Erupt3 Help Contents

Welcome to Erupt3 Help

(To learn how to use Help, press the F1 key)

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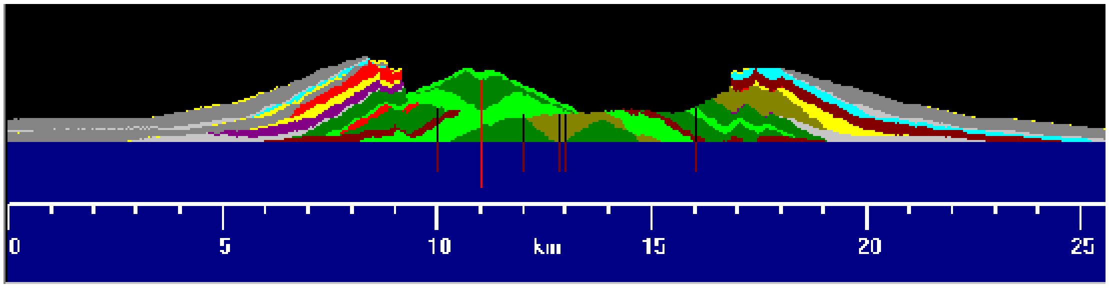

WWW: (Erupt3 Users Page) http://www.ees1.lanl.gov/Wohletz/Erupt-User.htm

Click on one of the general categories of help items below to get more information about this program.

Help Items (What's New for ERUPT 3):

If you have the Demo version of Erupt3 and would like to purchase it, please go to the RockWare site by clicking this link www.rockware.com.

ERUPT Version 3.0

This Windows Help file was written by Ken Wohletz

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Software Use Notice

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WWW: (Erupt3 Users Page) http://www.ees1.lanl.gov/Wohletz/Erupt-User.htm!

(Erupt Page) http://www.ees.lanl.gov/Wohletz/Erupt.htm!

Software by KWare: http://internet.cybermesa.com/~wohletz/KWare.htm

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Disclaimer:

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To register your version of Erupt see the registration help topic.

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To see what your current version of Erupt is, choose "about" from the help menu.

List of version changes for Erupt:

(Version)	(Notes)
v 1.0 (02/15/95)	Windows interface designed by Ken Wohletz.

v 1.5 (07/15/95)	Improved help screens and user interface
(12/01/95)	32-bit version compiled.
v 2.0 (09/09/96)	Multimedia sound added.
v 2.1 (10/15/96)	Minor visual improvements.
v 2.2 (10/18/96)	Added registration window.
v 2.3 (10/21/96)	Added sizeable viewing window.
v 2.4 (10/25/96)	Improved screen resolution.
v 3.00.0001b (09/03/97)	Beta version 1 of Erupt 3.0 commercial release, includes advanced parameters control detailed stratigraphic view geological and topographic maps (3-D) recording and playback of eruption sequences saving record files for later playback registry saving of user-options.
v 3.00.0002b (09/04/97)	Beta version 2 corrects display problem.
v 3.00.0003b (09/26/97)	Beta version 3 includes digital elevation model support changed stratigraphic file extension from ".top" to ".str", added "EruptDemo" files EruptDemo.str and EruptDemo.rec both of which will automatically enable maps.
v 3.00.0004b (12/10/97)	Beta version 4 improves printing capability, revises burst repetitions, and minor gliches.
v 3.00.0005b (01/08/98)	Beta version 5 adds improved scale rendering and vent position for auto mode, display of erupted phase volumes and VEI, improved help file, and legend fix. Also the sound files were upgraded to stereo.
v 3.00.0006b (05/15/98)	Beta version 6, compiled and optimized in native code, adds context sensitive help (via mouse click), improved help file, user settings via an options panel, speed control, a ToolBar, and mapping/topography display, a demonstration video, and a WWW browser to take users to the Erupt-Users page.
v 3.00.0007b (08/20/98)	Beta version 7 adds an update utility that uses FTP to check for newer versions of Erupt. Taskbar icons for various windows in Erupt were disabled (not needed), and several other small code changes were implemented.
v 3.00.0008b (02/24/99)	Beta version 8 adds sound volume control, particle number automation control, and a better scale change algorithm. The coding for eruption types has been greatly improved in simplicity and optimized, including the difficult task of scaling eruption types, depending upon scale size chosen.

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v 3.00.0010 (12/31/99)	First released version of Erupt 3.0. Compiled with updated components and an Erupt record file editor. A demo version is designed for web download; it disables updates and printing and is active for a 60-day trial only.
v 3.01.0030 (04/03/01)	After a number of minor revisions mostly concerning the optimization of Erupt Update and its FTP operation, this revision is more significant with addition of **Erupt3D Viewer**, an integrated application that uses DirectX 3D in order to display topographic plots in a full, user-controlled three-dimensional window. With revision .0033, a convenient Erupt3D vent positioning panel was added. In revision .0034, an undo button/parameter is added to undo the affects of the last

	simulated erupted event and an auto update notification option is added. In revision .0036 an "Undo" function is added to remove effects of last eruptive phase, the FTP connection is improved, and Auto Update Notification is added. Revision .0037 adds the required file "MSSTDFMT.DLL" to installations and updates, and revision .0038 fixes problem of closing an unregistered version while it is minimized.
v 3.02.0040 (09/13/01)	This revision is a major change in the registry usage and the Erupt3 data file path. It includes a settings update module that detects old settings and path and migrates them to those used by this version. Erupt Update now creates a log file of the update process and provides the option of downloading help files when in FTP mode, Erupt3D Viewer has been improved, and the registration module is updated to encourage sending registration information.
v 3.02 and later	Please see http://www.ees1.lanl.gov/Wohletz/Erupt-History.htmfor all future revision information

Getting Started

Erupt3 Installation Instructions:

For Purchased versions on CD:

1. Insert the Erupt 3 CD.
2. The setup program should automatically start. (If it does not, select "Run" from the Start Menu and enter "d:\win32\ersetup.exe" where "d" is the letter of your CD-ROM drive.)
3. You will be asked to enter a CD-Key Number, which is affixed to the back side of the CD case. Please don't loose this number. It will be retained by the system, and will not be required for re-installation, unless Windows is re-installed.
4. Follow the on-screen directions for installation. (If asked to restart Windows to continue, choose "yes", and after restarting, just reinsert the Erupt 3 CD to continue the setup.)
5. If during installation, a warning is given that a file cannot be copied or is in use, cancel the installation, close all applications, and start again as in step 2.
6. If there are problems, double-click the "Readme.txt" file in the root directory of the Erupt 3 CD for help.
7. Have fun Erupting!

For Downloaded versions:

1. Locate the folder where you downloaded the Erupt installation file ("Erupt3-Install.exe" or "Erupt.exe")
2. Double-click the downloaded file to start the installation
3. Follow the on-screen directions for installation. (If asked to restart Windows to continue, choose "yes", and after restarting, just repeat steps 1 and 2 above)
4. If during installation, a warning is given that a file cannot be copied or is in use, cancel the installation, close all applications, and start again as in step 2.
6. If there are problems, please send an email to "Erupt@lanl.gov" to get help.
7. When you first start Erupt3, you will be asked to register your version. Please follow the directions given for registration (its free!)
8. Have fun Erupting!

Learn About Erupt3: Probably the best way to learn about ERUPT is to read the program description and then something about its background. With this information proceed to reading the section on using ERUPT. ERUPT is a flexible programs with numerous options and ways to operate from very simplistic simulations to detailed reproductions of volcanic fields.

ERUPT consists of a main simulation window and stratigraphic, map, and topographic windows which can be superimposed. Simulation is achieved while working with the main simulation window. **Re-sizing** the simulation window to fit your screen is simply achieved by placing the mouse cursor over a border, holding down the left mouse button, and dragging the mouse to the desired position. By placing the mouse over the corner of the window, both height and width will be adjusted simultaneously.

Start an Eruption Simulation: To run erupt after starting the program, select an eruption type from the parameters menu, then proceed to the parameters panel and select "ok." Now the "Erupt" button will be activated so that you can start the eruption by pressing it. To stop the eruption at any point, simply press the "Pause/Stop" button twice.

Perhaps the easiest way to learn about what ERUPT can do is to choose the "Auto" erupt parameter and let the program entertain you. Alternatively, use the file menu to open the EruptDemo record file "EruptDemo.rec."

Please read the section on options, which will show you how to activate/deactivate sounds, enable 3D mapping and adjust other factors that determine how the program runs.

PLAY View a movie of Erupt in action!

Menu Selections

File: Allows user to start a new eruption sequence, open/save a stratigraphic file, digital elevation model, or eruption record file, setup printer and print, and exit ERUPT.

Parameters: Use this selection to choose among the various eruption styles, to select tectonic events, and to set the mode to auto or static.

Options: Program options such as sound, maps, map precision, scale, gravity, and simulation speed can be changed. Some of these option states will be saved and activated upon startup of Erupt.

Record: For recording, editing, and playback of eruption sequences.

View: For viewing and copying various windows: detailed stratigraphy, topography, map, and legend.

Help: Use this menu item to view the contents of this help file or view the "About ERUPT" window that has options to show an example movie, to view system information, and to see registration information.

Using Erupt3

Erupt3 installs a number of applications in a program folder listed in your Windows Start Menu. These are shown below.

Erup3 is the primary application you will use by clicking its icon, and its use is described below. All of the other applications are directly accessible from Erupt3 or they can be run alone by clicking their icon.

Erupt Comments: A program to send comments/problems and files created by Erupt3 to the Erupt FTP server where they will be reviewed
Erupt Edit: A utility to edit "recorder" files created by Erupt3 for customizing how a recorded file plays back within Erupt3
Erupt Update: A program to check if an updated version of Erupt3 and associated files is available; this program will also install the update
Erupt User Page: A link that will open your default web browser to the Erupt3 Users page for viewing information related to Erupt3
Erupt3 Help: A direct link to open this Erupt3 help file
Erupt3 Readme: A text file concerning installation of and notes about Erupt3
Erupt3: The main program, described below
Erupt3D Viewer: A program to view and print files created by Erupt3 in full 3D with the ability to navigate for different views and perspectives

Using Erupt3

Upon startup, the user generally selects an eruption type from the **Parameter menu** and then proceeds with adjusting (changing) the parameters for the selected event in the parameters panel. Then by pressing the "OK" button in the change window, ERUPT is ready to start by pressing the "ERUPT" button. Status bars at the top and bottom of the ERUPT window provide information about current settings and activities. Alternatively, the user may wish to open a saved stratigraphic file or record file first before choosing new ERUPT parameters. Also the user may wish first to change ERUPT options (such as speed, enable maps, scale, etc.).

From the **File menu**, the user can open and save files as well as print them. Erupt file formats include stratigraphic files, eruption record files, and digital elevation model files (DEM). After creating a volcano or volcanic fields, the user can save a file in one of the above formats; for eruption records the recording the recorder needs to have been activated prior to erupting, and for the DEM files the enable maps option must have been checked prior to erupting.

Options can be changed during the course of simulations. The user can disable sound, change the speed of the simulation, set the gravity to simulate conditions on other planets, enable and set the precision of mapping, and change the scale of the erupt window (note this feature will truncate data).

After completing an eruptive phase the user can use the **View menu** to see maps, topography, Erupt-3D, and detailed stratigraphy to see alternate portrayals of the evolving volcano or volcanic field. In addition, if the recorder is active, the simulation can be played back from the point at which the recorder was activated, and then after playback, the user can continue recording more eruptive phases.

The user may wish to make an image file of and eruption in progress, the stratigraphy, or maps. To do this use "Capture" in the view menu to activate the screen capture and then copy the screen image to the Windows clipboard.

There are many techniques that can be applied in simulations that make Erupt more realistic. Basically these techniques require some knowledge of volcanoes and their properties, morphology, and characteristic eruption history.

During an eruption, the extruded volume and volcanic explosivity index (VEI) is shown below the Erupt button. These values give an indication of how large a given eruptive phase is.

ERUPT is a program that benefits from users comments and is periodically updated. The user can the EruptUpdate program to keep their program current.

Detailed help for Erupt is available in this help file via the **Help menu** or by right clicking on any screen object. Technical problems encountered may be answered by the section on technical support.

PLAY View a movie of Erupt in action!

Erupt3 Background

Volcanoes and volcanic activity are captivating subjects, often a young person's first attraction to the natural sciences. By their very nature, however, volcanoes and their eruptions are difficult for most people to observe first hand, leaving us with our books, films, and imaginations. Simple home or school experiments, such as the reaction of baking soda with vinegar are fun to a limited extent, simply because they do not portray the awesome magnitude and power of a volcano as well as not really portraying the wide varieties of volcanic vents and eruption types. Even for the fortunate few that can visit volcanic parks, such as the Hawaiian Volcanoes National Park, the observation of volcanoes is limited to access and the rather narrow range of activity displayed. Nonetheless, computers bring the capability of making the science of volcanology much more real with their graphical capabilities. To be sure the physics of volcanoes, which underlies our knowledge of how volcanoes erupt and what those eruptions display, are very complex, often involving mathematical relationships that require complex solutions and solutions that vary rapidly with time. Such mathematical solutions provide pages of numbers that can be recast into graphical display, a technique called *numerical simulation*. Users of ERUPT can read the help section on Volcano Physics in order to get some background on how volcanoes erupt.

Work on the numerical simulation of volcanic eruptions began in the late 1970's at Los Alamos National Laboratory with the efforts of Tom McGetchin, Eric Jones, Maxwell "Brook" Sanford, and Ken Wohletz. These early efforts were dedicated to application of sophisticated numerical hydrodynamic computer codes, developed for study man-made explosions and the atmospheric effects of weapons, to understanding large volcanic eruptions. Published in the Journal of Geophysical Research in 1984, these studies showed the many possibilities for understanding volcanic eruptions that could not be gained from field studies or realistically obtained by volcano monitoring.

Ken Wohletz continued these efforts with help from Marty Horn and Greg Valentine throughout the 1980's, demonstrating the considerable utility of numerical simulations for volcanological research, and showing how newly developed *supercomputers* such as the Cray computers could make detailed simulations possible. However, the numerical sophistication and computer resources required by these types of simulations prevented most geologists from direct interaction with volcano simulation. For this reason, Ken Wohletz developed ERUPT to put simulation into the hands of geologist.

A manuscript describing details about Erupt can be viewed (using the Erupt WWW browser) online at:

www-geo.lanl.gov/Wohletz/Erupt-Doc.htm

Early versions of Erupt are available as shareware and can be downloaded from the internet at www-geo.lanl.gov/Wohletz/KWare.htm and www.rockware.com. Version history shows the evolution of this software product.

Advanced Topics

ERUPT is a very complex simulation built with a very simple user interface. However rather complex simulations can be achieved. A number of issues concerning use of this program revolve around the sophistication of the user and the computer hardware used for running ERUPT.

Rather than attempting to show parameter choices for a wide variety of eruption types, such as Surtseyan, Merapian, etc., Erupt shows parameters that simulate a range of eruption products that are produced by the various eruption types. For example, a Surtseyan eruption produced by water/magma interaction might result in a series of ballistic fallouts (similar to Strombolian) and pyroclastic surges (Similar to Vulcanian). By alternating these two parameters, a Surtseyan eruption can be simulated. Thus, the simulation does not focus on the driving variables of an eruption, such as the magma's dissolved gas fraction, viscosity, temperature, gas pressure, and volume flux, but rather attempts to combine these factors into simpler terms, encompassed by the parameters strength/Heim coefficient, number of particles, and the length of time (number of bursts) the user allows for each eruption. However, for those users who wish a bit more control on the overall eruptive effects, the eruption parameter panel has a button for Advanced Parameters, which control features such lava flow length, crater width, and for maps, the 3-D position of the vent. In the author's experience, practically any kind of volcanic eruption and any kind of volcano can be reproduced by careful combinations of these simple controlling parameters.

A measure of how large the simulated eruptive phase is given by the volume and VEI values shown just below the Erupt button on the Erupt window.

Sounds can be tailored by the user, using a sound file editor such as the one provided with Windows.

More advanced information can be viewed using the Erupt WWW Browser, and suggested techniques for using Erupt are discussed elsewhere in this file.

Erupt3 Glossary

This glossary contains definitions for volcano-related terms. Many of the terms below have been discussed in Volcano World (http://volcano.und.edu/starting_points.html) and reflect material in the following publications, which may serve the interested novice as good background material.

Audubon Society, *The Once and Future Mountain* (July, 1980)

Bullard, Fred M., *Volcanoes of the Earth* (London: University of Texas Press, 1976)

Bates, R.L., and Jackson, J.A., *Glossary of Geology* (American Geological Institute, 1987)

Decker and Decker, *Volcanoes* (W.H. Freeman and company, 1980)

Fisher, R.V., Heiken, G., and Hulen, J.B., *Volcanoes Crucibles of Change* (Princeton University Press, 1997)

Foxworthy and Hill, *Volcanic Eruptions of Mount St. Helens: The First 100 Days* (U.S. Geological Survey)

Francis, P., *Volcanoes* (Clarendon Press, 1993)

Korosec, *The 1980 Eruption of Mount St. Helens* (Washington State Department of Natural Resources)
MacDonald, Volcanoes (Prentice-Hall)

Macdonald, G.A., *Volcanoes* (Prentice-Hall, Inc., 1972)

Takahashi, T.J., and Griggs, J.D., *Hawaiian Volcanic Features: A Photoglossary* (U.S. Geological Survey Professional Paper 1350, v. 2, 1987).

Tilling, *Eruptions of Mount St. Helens: Past, Present and Future* (U.S. Geological Survey)

Williams, H. and McBirney, A.R., *Volcanology* (Freeman, Cooper & Co., 1979)

Aa: Hawaiian word used to describe a lava flow whose surface is broken into rough angular fragments.

Accretionary lava ball: A rounded mass, ranging in diameter from a few centimeters to several meters, [carried] on the surface of a lava flow such as aa, or on cinder-cone slopes, [and formed] by the molding of viscous lava around a core of already solidified lava.

Active volcano: A volcano that is erupting. Also, a volcano that is not presently erupting but that has erupted within historical time and is considered likely to do so in the future.

Agglutinate: A pyroclastic deposit consisting of an accumulation of originally plastic ejecta and formed by the coherence of the fragments upon solidification.

Alkalic: Rocks which contain above average amounts of sodium and/or potassium for the group of rocks for which it belongs. For example, the basalts of the capping stage of Hawaiian volcanoes are alkalic. They contain more sodium and/or potassium than the shield-building basalts that make the bulk of the volcano.

Andesite: Volcanic rock (or lava) characteristically medium dark in color and containing 54 to 62 percent silica and moderate amounts of iron and magnesium.

Ash: Fine particles of pulverized rock blown from an explosion vent. Measuring less than 1/10 inch in diameter, ash may be either solid or molten when first erupted. By far the most common variety is vitric ash, glassy particles formed by gas bubbles bursting through liquid magma.

Ashfall (airfall/fallout): Volcanic ash that has fallen through the air from an eruption cloud. A deposit so formed is usually well sorted and layered.

Aquifer: A body of rock that contains significant quantities of water that can be tapped by wells or springs.

Ash flow (pyroclastic flow): A turbulent mixture of gas and rock fragments, most of which are ash-sized particles, ejected violently from a crater or fissure. The mass of pyroclastics is normally of very high temperature and moves rapidly down the slopes, or even along a level surface.

Avalanche: A large mass of material or mixtures of material falling or sliding rapidly under the force of gravity. Avalanches often are classified by their content, such as snow, ice, soil, or rock avalanches. A mixture of these materials is a debris avalanche.

Basalt (Lava): Volcanic rock (or lava) that characteristically is dark in color, contains 45 to 54 percent silica, and generally is rich in iron and magnesium.

Blister: A swelling of the crust of a lava flow formed by the puffing-up of gas or vapor beneath the flow. Blisters are about 1 meter in diameter and hollow.

Block: Angular chunk of solid rock ejected during an eruption.

Bench: The unstable, newly-formed front of a lava delta.

Bomb: Fragment of molten or semi-molten rock, 2 1/2 inches to many feet in diameter, which is blown out during an eruption. Because of their plastic condition, bombs are often modified in shape during their flight or upon impact.

Caldera: The Spanish word for cauldron, a basin-shaped volcanic depression; by definition, at least a mile in diameter. Such large depressions are typically formed by the subsidence of volcanoes. Crater Lake occupies the best-known caldera in the Cascades.

Capping stage: Refers to a stage in the evolution of a typical Hawaiian volcano during which alkalic basalt and related rocks build a steeply sloping cap on the main shield of the volcano. Eruptions are less frequent but more explosive. Summit caldera may be buried.

Cenozoic: An era of geological history comprising the Tertiary and Quaternary Periods from about 70 million years ago until today; rocks and geological events occurring during this era.

Central Vent: A central vent is an opening at the Earth's surface of a volcanic conduit of cylindrical or pipelike form.

Central Volcano: A volcano constructed by the ejection of debris and lava flows from a central point, forming a more or less symmetrical volcano.

Cinder cone: A volcanic cone built entirely of loose fragmented material (pyroclastics.)

Cirque: A steep-walled horseshoe-shaped recess high on a mountain that is formed by glacial erosion.

Cleavage: The breaking of a mineral along crystallographic planes, this reflecting crystal structure.

Columnar jointing: Contraction during cooling of thick, extrusive basaltic lava flows causes cracks perpendicular to the cooling surface, which form the polygonal columns of the Devil's Postpile in California. The columns average about 46 cm across. In thick, slowly cooled flows, the joints normal to the flow surface tend to develop in three directions at roughly 60-degrees to each other and form multi-sided blocks that are cut off by the joints parallel to the flow surface. Jointing of this sort may attain a high degree of regularity. The horizontal joints divide the columns into a series of segments. Such columnar jointing is found in all types of lava flows, including ash flows. It is also conspicuous in dikes and other intrusions.

Composite Volcano: A steep volcanic cone built by both lava flows and pyroclastic eruptions.

Compound Volcano: A volcano that consists of a complex of two or more vents, or a volcano that has an associated volcanic dome, either in its crater or on its flanks. Examples are Vesuvius and Mont Pelée.

Compression waves: Earthquake waves that move like a slinky. As the wave moves to the left, for example, it expands and compresses in the same direction as it moves.

Conduit: A passage followed by magma in a volcano.

Continental crust: Solid, outer layers of the earth, including the rocks of the continents, typically silicic igneous rocks, metamorphic rocks, and sedimentary rocks.

Continental Drift: The theory that horizontal movement of the earth's surface causes slow, relative movements of the continents toward or away from one another.

Crater: A steep-sided, usually circular depression formed by either explosion or collapse at a volcanic vent.

Craton: A part of the earths crust that has attained stability, and has been little deformed for a prolonged period.

Curtain of fire: A row of coalescing lava fountains along a fissure; a typical feature of a Hawaiian-type eruption.

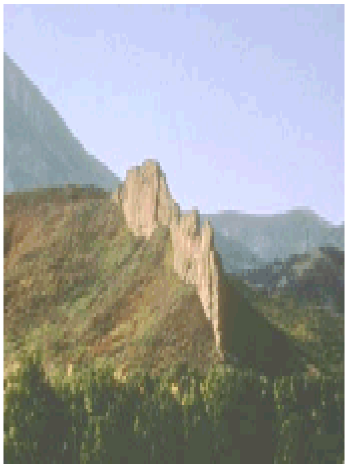
Dacite: Volcanic rock (or lava) that characteristically is light in color and contains 62 to 69 percent silica and moderate a mounts of sodium and potassium.

Debris avalanche: A rapid and unusually sudden sliding or flowage of unsorted masses of rock and other material. As applied to the major avalanche involved in the eruption of Mount St. Helens, a rapid mass movement that included fragmented cold and hot volcanic rock, water, snow, glacier ice, trees, and some hot pyroclastic material. Most of the May 18 deposits in the upper valley of the North Fork Toutle River and in the vicinity of Spirit Lake are from the debris avalanche.

Debris Flow: A mixture of water-saturated rock debris that flows downslope under the force of gravity (also called lahar or mudflow).

Detachment plane: The surface along which a landslide disconnects from its original position.

Diatreme: A diatreme is a deep-rooted volcano, formed by rise of gas-rich magma from the mantle along a pipe-like or fissure conduit.



Dike: A tabular igneous intrusion that cuts across the bedding of the country rock, generally in a more or less vertical orientation.

Dome: A steep-sided mass of viscous (doughy) lava extruded from a volcanic vent, often circular in plane view and spiny , rounded, or flat on top. Its surface is often rough and blocky as a result of fragmentation of the cooler, outer crust during growth of the dome.

Dormant volcano: Literally, "sleeping". The term is used to describe a volcano which is presently inactive but which may erupt again. Most of the major Cascade volcanoes are believed to be dormant rather than extinct.

Drainage Basin: The area of land drained by a river system.

Echelon: Said of geologic features that are in an overlapping or staggered arrangement, for example faults. Each is relatively short but collectively they form a linear zone, in which the strike of the individual features is oblique to that of the zone as a whole.

Ejecta: Material that is thrown out by a volcano, including pyroclastic material (tephra) and, from some volcanoes, lava bombs.

Episode: An episode is a volcanic event that is distinguished by its duration or style.

Eruption: The process by which solid, liquid, and gaseous materials are ejected into the earth's atmosphere and onto the earth's surface by volcanic activity. Eruptions range from the quiet overflow of liquid rock to the tremendously violent expulsion of pyroclastics.

Eruption cloud: The column of gases, ash, and larger rock fragments rising from a crater or other vent. If it is of sufficient volume and velocity, this gaseous column may reach many miles into the stratosphere, where high winds will carry it long distances.

Eruptive vent: The opening through which volcanic material is emitted.

Evacuate: Temporarily move people away from possible danger.

Extinct volcano: A volcano that is not presently erupting and is not likely to do so for a very long time in the future.

Fault: A crack or fracture in the earth's surface. Movement along the fault can cause earthquakes or, in the process of mountain-building, can release underlying magma and permit it to rise to the surface.

Fault scarp A steep slope or cliff formed directly by movement along a fault and representing the exposed surface of the fault before modification by erosion and weathering.

Felsic: An igneous rock having abundant light-colored minerals.

Fissures: Elongated fractures or cracks on the slopes of a volcano. Fissure eruptions typically produce liquid flows, but pyroclastics may also be ejected.

Flank eruption: An eruption from the side of a volcano (in contrast to a summit eruption.)

Fluvial: Produced by the action of flowing water.

Formation: A body of rock identified by lithic characteristics and stratigraphic position and is mappable at the earth's surface or traceable in the subsurface.

Fumarole: A vent or opening through which issue steam, hydrogen sulfide, or other gases. The craters of many dormant volcanoes contain active fumaroles and display fumarolic/phreatic eruptions.

Geothermal energy: Energy derived from the internal heat of the earth.

Geothermal power: Power generated by using the heat energy of the earth.

Graben: An elongate crustal block that is relatively depressed (downdropped) between two fault systems.

Guyot: A type of seamount that has a platform top. Named for a nineteenth-century Swiss-American geologist.

Hardness: The resistance of a mineral to scratching.

Harmonic tremor: A continuous release of seismic energy typically associated with the underground movement of magma. It contrasts distinctly with the sudden release and rapid decrease of seismic energy associated with the more common type of earthquake caused by slippage along a fault.

Hawaiian eruptions: This type of eruption is typical of lava flow activity in Hawaii.

Heat transfer: Movement of heat from one place to another. Generally this transfer occurs by conduction within the earth, but if fluids (water, magma) are moving, heat transfer occurs also by convection. Generally rocks and magma are not hot enough to transfer much heat by radiation.

Heterolithologic: Material is made up of a heterogeneous mix of different rock types. Instead of being composed on one rock type it is composed of fragments of many different rocks.

Holocene: The time period from 10,000 years ago to the present; also, the rocks and deposits of that age.

Horizontal blast: An explosive eruption in which the resultant cloud of hot ash and other material moves laterally rather than upward.

Hot Spot: A volcanic center, 60 to 120 miles (100 to 200 km) across and persistent for at least a few tens of million of years, that is thought to be the surface expression of a persistent rising plume of hot mantle material. Hot spots are not linked to arcs, and may not be associated with ocean ridges.

Hot-spot volcanoes: Volcanoes that are related to a persistent heat source in the mantle.

Hyaloclastite: A deposit formed by the flowing or intrusion of lava or magma into water, ice, or water-saturated sediment, and its consequent granulation or shattering into small angular fragments.

Hydrothermal reservoir: An underground zone of porous rock containing hot water.

Hypocenter: The place on a buried fault where an earthquake occurs.

Ignimbrite: The rock formed by the widespread deposition and consolidation of ash flows and nuées ardentes (see welded tuff). The term was originally applied only to densely welded deposits but now includes non-welded deposits.

Intensity: A measure of the effects of an earthquake at a particular place. Intensity depends not only on the magnitude of the earthquake but also on the distance from the epicenter and the local geology.

Intrusion: The process of emplacement of magma in pre-existing rock. Also refers to igneous rock mass so formed within the surrounding rock.

Joint: A surface of fracture in a rock.

Kipuka: An area surrounded by a lava flow.

Laccolith: A body of igneous rocks with a flat bottom and domed top. It is parallel to the layers above and below it.

Lahar: A torrential flow of water-saturated volcanic debris down the slope of a volcano in response to gravity. A type of mudflow.

Landsat: A series of unmanned satellites orbiting at about 706 km (438 miles) above the surface of the Earth. The satellites carry cameras similar to video cameras and take images or pictures showing features as small as 30 m or 80 m wide, depending on which camera is used.

Lapilli: Literally, "little stones"; round to angular rock fragments measuring 1/10 inch to 2 1/2 inches in diameter, which may be ejected in either a solid or molten state.

Lava: Magma which has reached the surface through a volcanic eruption. The term is most commonly applied to streams of liquid rock that flow from a crater or fissure. It also refers to cooled and solidified rock.

Lava flow: An outpouring of lava onto the land surface from a vent or fissure. Also, a solidified tongue like or sheet like body formed by outpouring lava.

Lava lake (pond): A lake of molten lava, usually basaltic, in a volcanic crater or depression. The term refers to solidified and partially solidified stages as well as to the molten, active lava lake.

Lava shield: A shield volcano made of basaltic lava.

Lava tube: A tunnel formed when the surface of a lava flow cools and solidifies, while the still-molten interior flows through and drains away.

Limu o Pele (Pele seaweed): Delicate, translucent sheets of spatter filled with tiny glass bubbles.

Lithic Of or pertaining to stone.

Lithosphere: The rigid crust and uppermost mantle of the Earth. Thickness is on the order of 60 miles (100 km). Stronger than the underlying asthenosphere.

Luster: The reflection of light from the surface of a mineral.

Maar: A volcanic crater that is produced by an explosion in an area of low relief, is generally more or less circular, and often contains a lake, pond, or marsh.

Mafic: An igneous composed chiefly of one or more dark-colored minerals.

Magma: Molten rock beneath the surface of the earth.

Magma chamber: The subterranean cavity containing the gas-rich liquid magma which feeds a volcano.

Mantle: The zone of the earth bel ow the crust and above the core.

Magnitude: A numerical expression of the amount of energy released by an earthquake, determined by measuring earthquake waves on standardized recording instruments (seismographs.) The number scale for magnitudes is logarithmic rather than arithmetic; therefore, deflections on a seismograph for a magnitude 5 earthquake, for example, are 10 times greater than those for a magnitude 4 earthquake, 100 times greater than for a magnitude 3 earthquake, and so on.

Matrix: The solid matter in which a fossil or crystal is embedded. also, a binding substance, as cement in concrete.

Mesozoic: An era of geological history comprising the Cretaceous, Jurassic, and Triassic Periods from about 225 to 70 million years ago; best known as the age of dinosaurs; rocks and geological events occurring during this era.

Miocene: A epoch in Earth history from about 24 to 11 million years ago. Also refers to the rocks that formed in that epoch.

Moho: Also called the Mohorovicic discontinuity. The surface or discontinuity that separates the crust from the mantle. The Moho is at a depth of 5-10 km beneath the ocean floor and about 35 km below the continents (but down to 60 km below mountains). Named for Andrija Mohorovicic a Croatian seismologist.

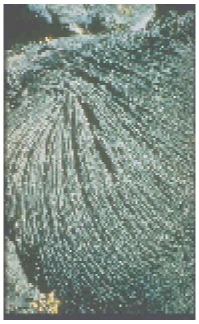
Monogenetic: A volcano built by a single eruption.

Mudflow: A flowage of water-saturated earth material possessing a high degree of fluidity during movement. A less-saturated flowing mass is often called a debris flow. A mudflow originating on the flank of a volcano is properly called a lahar.

Nuée ardente: A French term applied to a highly heated mass of gas-charge ash which is expelled with explosive force, and hurricane speed, down the mountainside, essentially synonymous with the term pyroclastic flow.

Obsidian: A black, brown, gray, or reddish-colored volcanic glass, usually composed of silicic lava.

Oceanic crust: The earth's crust where it underlies oceans; in many places it is composed of basaltic lava.



Pahoehoe: A Hawaiian term for lava with a smooth, billowy, or ropey surface.

Paleozoic: An era of geological history comprising the Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian Periods from about 600 to 225 million years ago until today; rocks and geological events occurring during this era.

Pali: Hawaiian word for steep hills or cliffs.

Parameters: For this Erupt program, parameters are numerical values that determine the physical nature of a given eruption style are set to default values unless specified by the user in the parameter panel.

Peralkaline: Igneous rocks in which the molecular proportion of aluminum oxide is less than that of sodium and potassium oxides combined.

Pele's hair: A natural spun glass formed by blowing-out during quiet fountaining of fluid lava, cascading lava falls, or turbulent flows, sometimes in association with Pele's tears. A single strand, with a diameter of less than half a millimeter, may be as long as two meters.

Pele's tears: Small, solidified drops of volcanic glass behind which trail pendants of Pele hair. They may be tear-shaped, spherical, or nearly cylindrical.

Peléean eruption: This eruption type involves growth of lava domes and spires accompanied by explosive blasts

Phenocryst: A crystal, from about 1 mm to several cm in width, embedded in porphyritic igneous rock. Volcanic rocks often contain tiny crystals of quartz, feldspar, olivine, and pyroxene.

Phreatic eruption (explosion): An explosive volcanic eruption caused when water and heated volcanic rocks interact to produce a violent expulsion of steam and pulverized rocks. Magma is not involved.

Phreatomagmatic: An explosive volcanic eruption that results from the interaction of surface or subsurface water and magma.

Pillow lava: Interconnected, sack-like bodies of lava formed under water.

Pit crater: A crater formed by sinking in of the surface; not primarily a vent for lava.

Plate tectonics: The theory that the earth's crust is broken into about 10 fragments (plates,) which move in relation to one another, shifting continents, forming new ocean crust, and stimulating volcanic eruptions.

Pleistocene: A epoch in Earth history from about 2 million years to 10,000 years ago. Also refers to the rocks and sediment deposited in that epoch.

Pliocene: A epoch in Earth history from about 11 to 2 million years. Also refers to the rocks and sediment deposited in that epoch.

Plinian eruption: An explosive eruption in which a steady, turbulent stream of fragmented magma and magmatic gases is released at a high velocity from a vent. Large volumes of tephra and tall eruption columns are characteristic.

Plug: Solidified lava and pyroclastic material that fills the conduit of a volcano (see volcanic neck). It is usually more resistant to erosion than the material making up the surrounding cone, and may remain standing as a solitary pinnacle when the rest of the original structure has eroded away.

Plug dome: The steep-sided, rounded mound formed when viscous lava wells up into a crater and is too stiff to flow away. It piles up as a dome-shaped mass, often completely filling the vent from which it emerged.

Pluton: A large igneous intrusion formed at great depth in the crust.

Precambrian: All geologic time from the beginning of Earth history to about 600 million years ago. Also refers to the rocks that formed in that epoch.

Polygenetic: Originating in various ways or from various sources.

Pumice: Light-colored, frothy volcanic rock, usually of dacite or rhyolite composition, formed by the expansion of gas in erupting lava. Commonly seen as lumps or fragments of pea-size and larger, but can also occur abundantly as ash-sized particles.

Pyroclastic: Pertaining to fragmented (clastic) rock material formed by a volcanic explosion or ejection from a volcanic vent.

Pyroclastic flow/surge: Lateral flowage of a turbulent mixture of hot gases and unsorted pyroclastic material (volcanic fragments, crystals, ash, pumice, and glass shards) that can move at high speed (50 to 100 miles an hour.) The term also can refer to the deposit so formed.

Quaternary: The period of Earth history from about 2 million years ago to the present; also, the rocks and deposits of that age.

Relief: The vertical difference between the summit of a mountain and the adjacent valley or plain.

Repose: The interval of time between volcanic eruptions.

Renewed volcanism stage: Refers to a stage in the evolution of a typical Hawaiian volcano during which, after a long period of quiescence, lava and tephra erupt intermittently. Erosion and reef building continue.

Rhyodacite: An extrusive rock intermediate in composition between dacite and rhyolite.

Rhyolite: Volcanic rock (or lava) that characteristically is light in color, contains 69 percent silica or more, and is rich in potassium and sodium.

Ridge, Oceanic: A major submarine mountain range.

Rift system: The oceanic ridges formed where tectonic plates are separating and a new crust is being created; also, their on-land counterparts like the East African Rift.

Rift zone: A zone of volcanic features associated with underlying dikes. The location of the rift is marked by cracks, faults, and vents.

Ring of Fire: The regions of mountain-building earthquakes and volcanoes which surround the Pacific Ocean.

Scoria: A bomb-size (> 64 mm) pyroclast that is irregular in form and generally very vesicular. It is usually heavier, darker, and more crystalline than pumice.

Seafloor spreading: The mechanism by which new seafloor crust is created at oceanic ridges and slowly spreads away as plates are separating.

Seamount: A submarine volcano.

Sector Collapse: When the flanks of a high-standing volcano (e.g., composite cone or dome) become unstable, a portion or sector of the volcano may break loose and slide down hill as an avalanche.

Seismograph: An instrument that records seismic waves; that is, vibrations of the earth.

Seismologist: scientists who study earthquake waves and what they tell us about the inside of the Earth.

Seismometer: an instrument that measures motion of the ground caused by earthquake waves.

Shearing: The motion of surfaces sliding past one another.

Shear waves: earthquake waves that move up and down as the wave itself moves, for example, to the left.

Shield volcano: A gently sloping volcano in the shape of a flattened dome, built almost exclusively of lava flows.

Shock wave: A compression wave that travels through the air or rock at greater than the speed of sound. Large volcanic explosions can drive shock waves through the atmosphere. These waves can have large overpressures that damage buildings, produce "sonic booms" loud enough to injure the human ear, and produce disorientation in humans and animals.

Shoshonite: A trachyandesite composed of olivine and augite phenocrysts in a groundmass of labradorite with alkali feldspar rims, olivine, augite, a small amount of leucite, and some dark-colored glass. It's name is derived from the Shoshone River, Wyoming, and given by Iddings in 1895.

Silica: A chemical combination of silicon and oxygen.

Silicic Lava: This lava, termed rhyolite or dacite, is a medium grey to nearly white in color and can be black if it is obsidian or even a brown to reddish brown color.

Sill: A tabular igneous intrusion that follows the bedding of the country rock, generally in a more or less horizontal orientation.

Skylight: An opening, formed by collapse, in the roof of a lava tube.

Solfatara: A type of fumarole, the gases of which are characteristically sulfurous.

Spatter cone: A low, steep-sided cone of spatter built up on a fissure or vent; it is usually of basaltic material.

Spatter rampart: A ridge of congealed pyroclastic material, usually basaltic, built up on a fissure or vent.

Specific gravity: The density of a mineral divided by the density of water.

Spines: Horn-like projections formed upon a lava dome.

Stratigraphic: The study of rock strata, especially of their distribution, deposition and age.

Stratovolcano: A volcano composed of both lava flows and pyroclastic material.

Strike-slip fault: A nearly vertical fault with side-slipping displacement.

Strombolian eruption: A type of volcanic eruption characterized by jetting of clots or fountains of fluid basaltic lava from a central crater.

Subduction zone: The zone of convergence of two tectonic plates, one of which usually overrides the other.

Surge: A ring-shaped cloud of gas and suspended solid debris that moves radially outward at high velocity as a density flow from the base of a vertical eruption column accompanying a volcanic eruption or crater formation.

Tectonic: Refers to geological processes that deform the earth's crust, including faulting, folding, uplifts, and rifting.

Tephra: Materials of all types and sizes that are erupted from a crater or volcanic vent and deposited from the air.

Tertiary: The period of Earth history from about 70 to 2 million years ago; also, the rocks and deposits of that age.

Tilt: The angle between the slope of a part of a volcano and some reference. The reference may be the slope of the volcano at some previous time.

Trachyandesite: An extrusive rock intermediate in composition between trachyte and andesite.

Trachybasalt: An extrusive rock intermediate in composition between trachyte and basalt.

Trachyte: A group of fine-grained, generally porphyritic, extrusive igneous rocks having alkali feldspar and minor mafic minerals as the main components, and possibly a small amount of sodic plagioclase.

Tremor: Low amplitude, continuous earthquake activity often associated with magma movement.

Tsunami: A great sea wave produced by a submarine earthquake, volcanic eruption, or large landslide.

Tuff: Rock formed of consolidated pyroclastic material.

Tuff cone: A type of volcanic cone formed by the interaction of basaltic magma and water. Smaller and steeper than a tuff ring.

Tuff ring: A wide, low-rimmed, well-bedded accumulation of hyaloclastic debris built around a volcanic vent located in a lake, coastal zone, marsh, or area of abundant ground water.

Tumulus: A doming or small mound on the crest of a lava flow, caused by pressure due to the difference in the rate of flow between the cooler crust and the more fluid lava below.

Ultramafic: Igneous rocks made mostly of the mafic minerals hypersthene, augite, and/or olivine.

Unconformity: A substantial break or gap in the geologic record where a rock unit is overlain by another that is not next in stratigraphic succession, such as an interruption in continuity of a depositional sequence of sedimentary rocks or a break between eroded igneous rocks and younger sedimentary strata. It results from a change that caused deposition to cease for a considerable time and it normally implies uplift and erosion with loss of the previous formed record.

Vent: The opening at the earth's surface through which volcanic materials issue forth.

Vesicle: A small air pocket or cavity formed in volcanic rock during solidification.

Viscosity: A measure of resistance to flow in a liquid (water has low viscosity while honey has a higher viscosity.)

Volcano: A vent in the surface of the Earth through which magma and associated gases and ash erupt; also, the form or structure, usually conical, that is produced by the ejected material. Here are some spellings of the word in other languages.

Chinese:	Huoshan
Danish:	vulkan
Dutch:	vulkaan
Esperanto:	vulkano
French:	volcan
German:	vulkan
Hawaiian:	lua pele
Indonesian:	gunung berap
Italian:	monte ignivoma
Japan:	kazan
Norwegian:	vulkan
Polish:	wulkan
Portuguese:	vulcao
Russian:	vulkan
Somali:	volkano
Spanish:	vulcan
Swahili:	voleno
Sedish:	vulkan
Syrian Arabic:	berkaan
Vietnamese:	nui lua
Welch:	llosgfynydd and folcano
Zulu:	intabomlilo

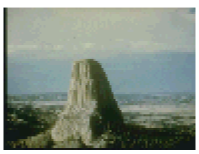
Volcanic arc: A generally curved linear belt of volcanoes above a subduction zone, and the volcanic and plutonic rocks formed there.

Volcanic complex: A persistent volcanic vent area that has built a complex combination of volcanic landforms.

Volcanic Explosivity Index (VEI): A scale from 0 to 8 that is a ranking of an eruption's explosivity by the volume of fragmental ejecta (pyroclastic rocks) it produces.

Volcanic gases: Water vapor (H_2O), carbon dioxide (CO_2), and sulfur dioxide (SO_2) are the most common volcanic gases. In lesser amounts, volcanoes release carbon monoxide (CO), hydrogen sulfide (H_2S), carbonyl sulfide (COS), carbon disulfide (CS_2), hydrogen chloride (HCl), hydrogen (H_2), methane (CH_4), hydrogen fluoride (HF), boron, hydrogen bromine (HBr), mercury (Hg) vapor, organic compounds, even gold.

Volcanic glass: Lava that has cooled very rapidly becomes homogeneous with few or no crystals. It is often semi-translucent, varying from a light-gray to black in color, often with a shiny, smooth surface. Obsidian is a common form of volcanic glass.

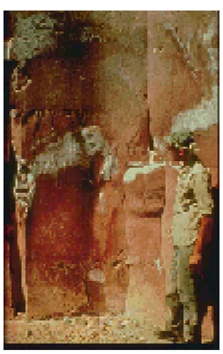


Volcanic neck: A massive pillar of rock more resistant to erosion than the lavas and pyroclastic rocks of a volcanic cone.

Vulcan: Roman god of fire and the forge, after whom volcanoes are named.

Vulcanian: A type of eruption consisting of the explosive ejection of incandescent fragments of new viscous lava, usually on the form of blocks.

Water table: The surface between where the pore space in rock is filled with water and where the pore space in rock is filled with air.



Welded tuff: A rock unit formed by compaction and consolidation of hot pumice and ash shortly after it is erupted and emplaced. The compaction occurs as gases escape from the pumice and ash while they viscously deform and sinter under the weight of overlying material. The resulting rock is dense and hard and can look like lava.

Xenolith: A foreign inclusion in an igneous rock.

Erupt3 Description

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ERUPT is a graphical program that simulates various volcanic eruption types, including Strombolian, Plinian, Vulcanian/Surtseyan, Hawaiian lava flows, Peléean viscous lava dome emplacement, Fumarolic/Phreatic activity, and sector collapse. Tectonic (faulting) and erosional events are also simulated.

This program is designed for a computer running Windows 95 or NT. The simulation speed is determined in general by your processor type, the program determines your processor speed to best show simulations. For faster or slower simulations adjust the speed parameter under the Options menu.

Parameter selection allows a manual and automatic mode for setting the eruption parameters. The manual mode allows the user to specify eruption type, magnitude, and vent location, and will continue in that mode until the user presses any key to stop the current eruptive phase and start a new one. The automatic mode of this program runs simulations that follows semi-random eruption scenarios of silicic, intermediate, or mafic trends with time.

Each eruptive phase produces a color-coded stratigraphic representation of the erupted products, such that complex volcanic stratigraphies can be created. Current program memory allocations allow up to 100 eruptive phases to be superimposed, after which only static (no deposition) eruptions may be specified. The user has the option to switch between manual and automatic mode of operation at any time after completion of an eruptive phase. Also, the stratigraphic cross section can be saved in a user-named file prior to exiting the program or restarting it.

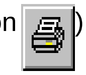
The horizontal (vertical with no exaggeration) scale is calibrated to kilometers, but if larger screen portrayals of Strombolian bursts are desired, the eruptive strength can be increased beyond the limit of 1.0, which results in scoria dispersal that is beyond that of typical Strombolian ranges.

A default stratigraphic profile can be loaded at startup time if desired or a user-named one, if a previously saved one is on the disk.

New options have been added for Erupt version 3.x. These include the ability to produce plan-view maps and topographic representations in a pseudo 3-D format, to record and playback an eruption sequence, and setting the scale of view.

HAVE FUN ERUPTING!!!

Erupt3 Simulation Window

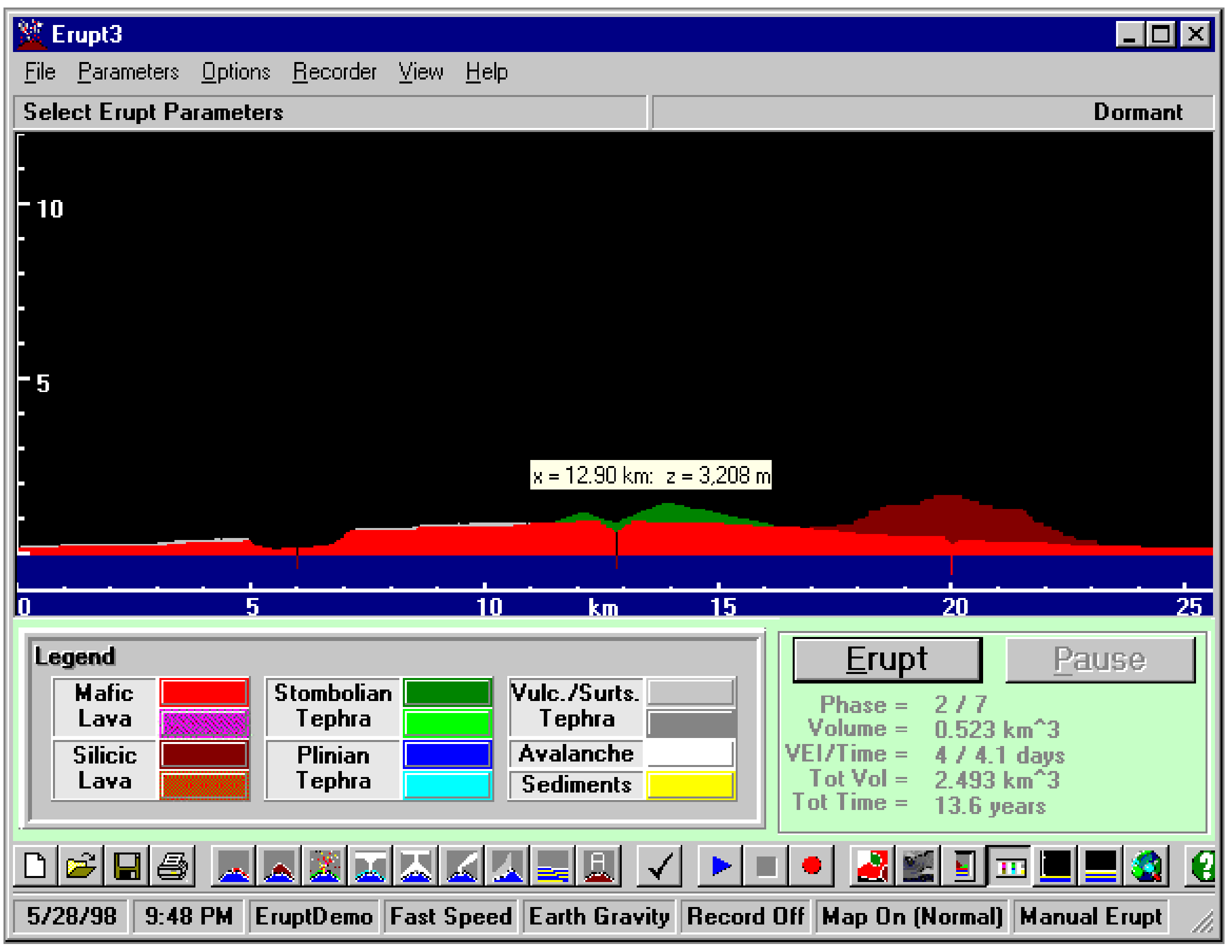
The Erupt window (the main window) shows simulation controls and the simulation window. The window can be printed (choose file/print or press the toolbar icon ).

Importantly, this window can be sized by using the mouse to select a corner or side, depressing the left mouse button and holding it down while dragging the mouse to a larger or smaller window size. This action helps to better fit your screen area. The size chosen determines the size of the stratigraphy, map, and topography windows when they are displayed. Upon exiting Erupt, the size and position will be saved for future sessions.

When the cursor is passed over the simulation window, a cross-hair appears showing the horizontal location and elevation. The Erupt window consists of the simulation area, a status bar showing current simulation events just above the simulation area, panels showing a Legend (pictured below) or eruption/tectonic parameters, the Erupt and Halt buttons, current simulation phase volume and VEI, an optional and customizable ToolBar at the base, and a second status bar at the very base of the window, which shows current date and time, options selected, and file opened.

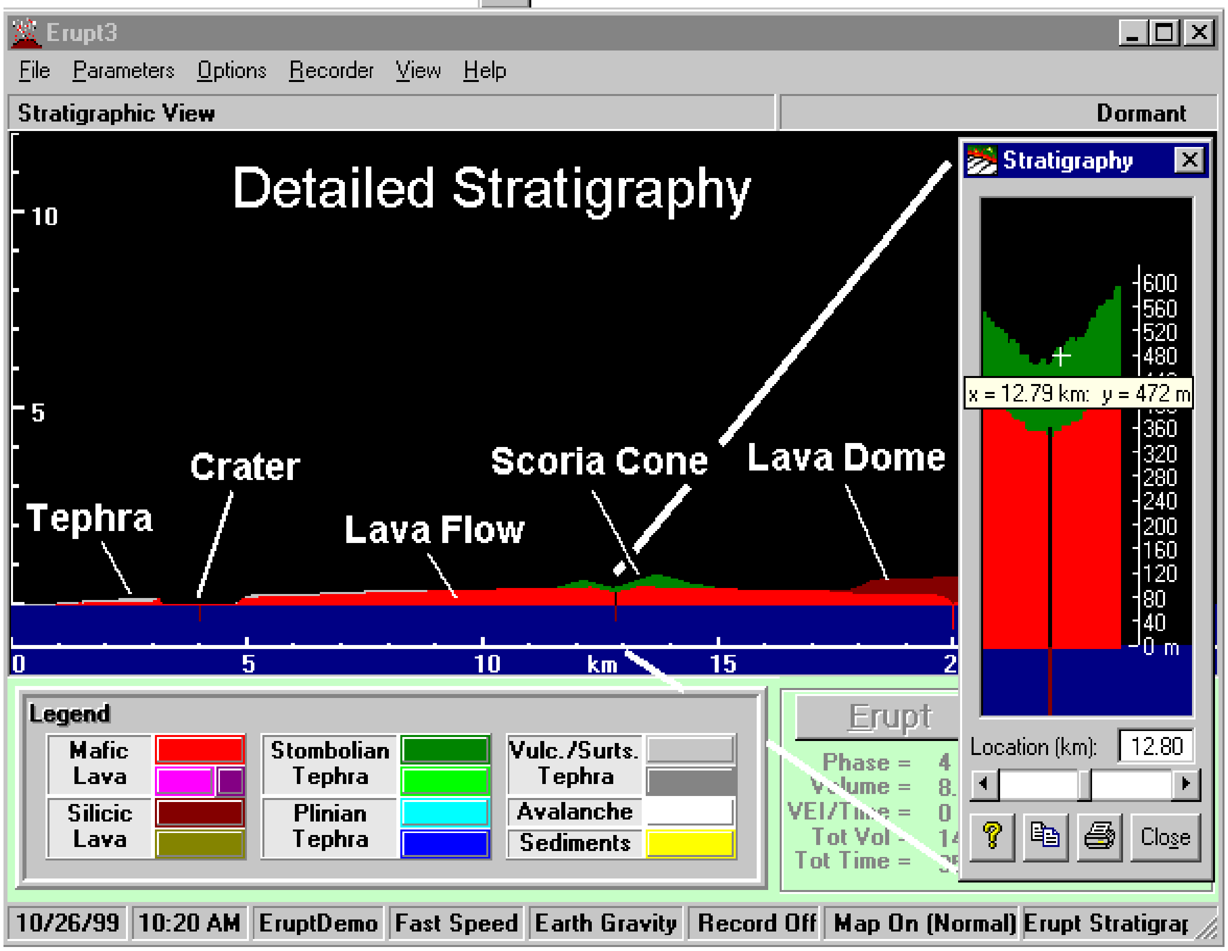
For most elements in this window, a right mouse click will bring up the associated help item.

For **Erupt3 Demo** versions, a label is superimposed in the upper left-hand corner of the map. This label does not appear in retail versions. In addition, printing is disabled in demo versions.



Detailed Stratigraphy

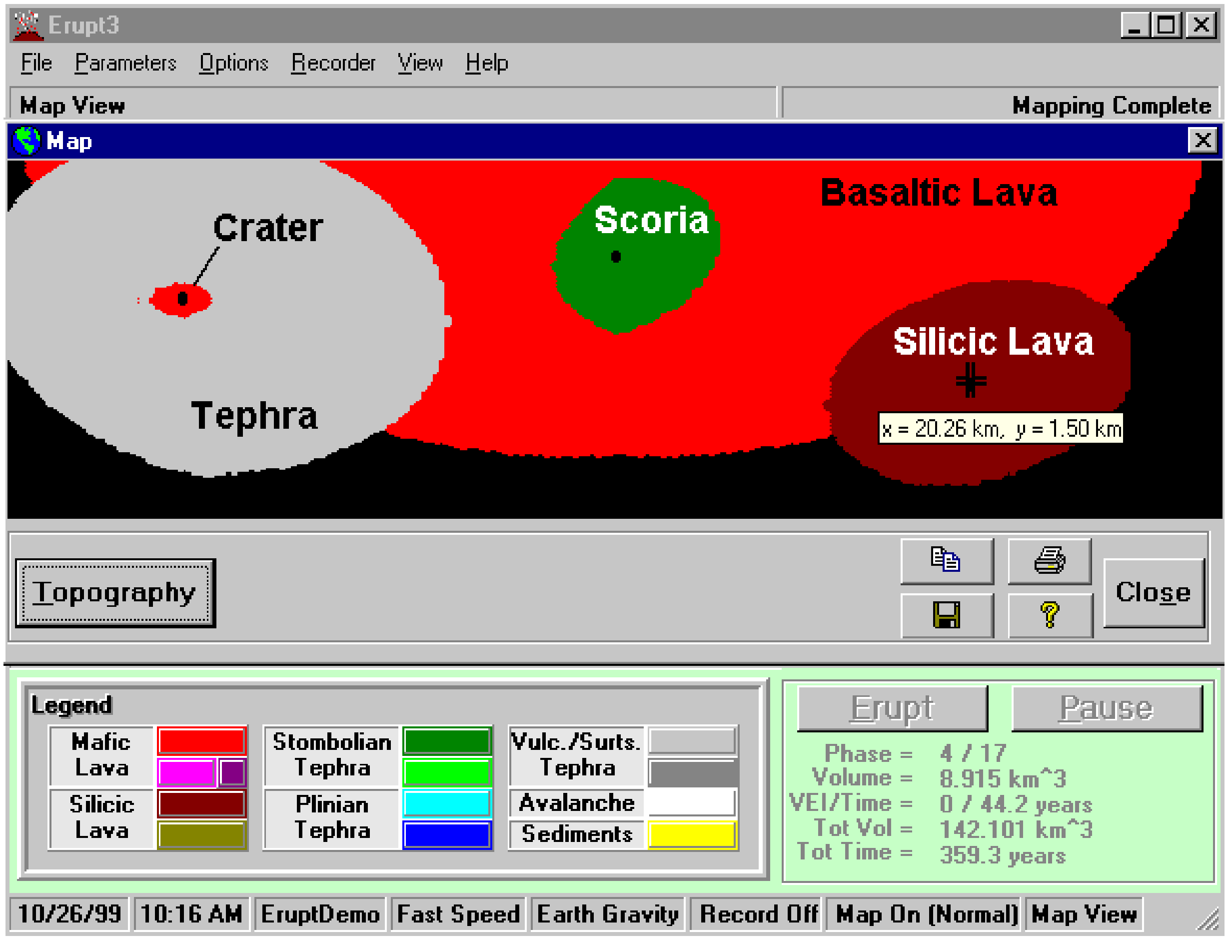
When the option "stratigraphy" is chosen from the view menu, a columnar window will appear with a "zoomed" view of the stratigraphy at any position. To change the view position, the scroll bar must be used. The various colors shown in the detailed stratigraphy window are keyed to the legend. This view allows the user to see the nature of contacts among the various strata that may not be readily apparent in the main erupt window. In addition the "Copy" button allows copying the topographic image to the Windows clipboard, and the Print button will display the print panel for the detailed stratigraphy



Map Window

The Map window is displayed when View/Map is chosen from the menu. The map window displays buttons for showing the topographic map, copying the map image to the Windows clipboard, saving a bitmap image of the map , printing , or closing the map window. The cursor displays the horizontal (x) and 3D (y) position for any point it passes over.

For **Erupt3 Demo** versions, a label is superimposed in the upper left-hand corner of the map. This label does not appear in retail versions. In addition, printing is disabled in demo versions.

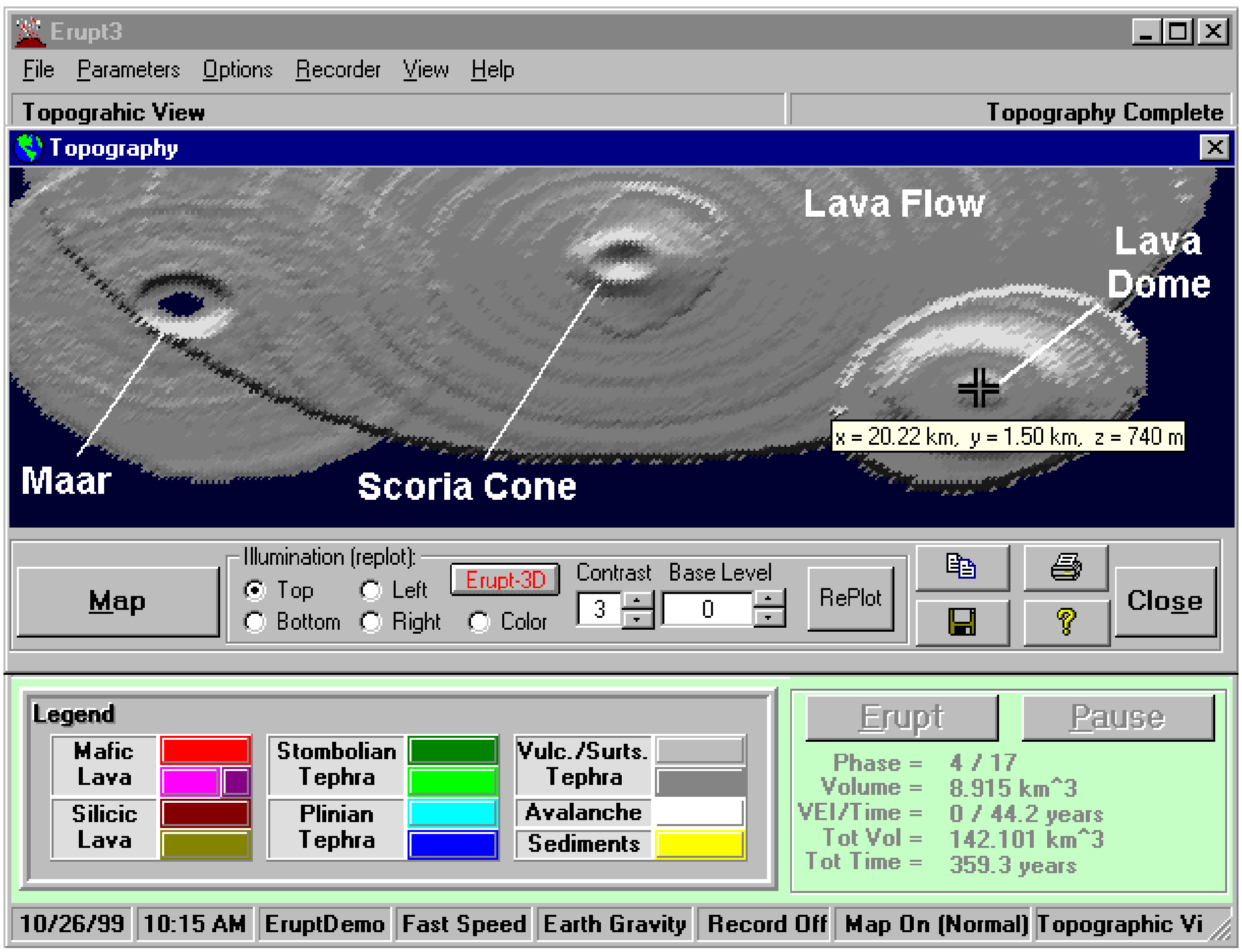


Topography Window

The Topography window is displayed when View/Topography is chosen from the menu or the topography button is pressed when viewing the geological map. The topography window displays buttons for showing the geologic map, copying the topographic image to the Windows clipboard, saving a bitmap image of the topography, printing, or closing the map window. In addition, options are displayed for the user to choose the desired **illumination** effect. If another illumination is selected, the topography will be drawn with the selected illumination.The options for top, left, bottom, and right designate the direction of lighting. The **color** option portrays the topographic map with elevations shown by a color scheme where warmer colors are used for higher elevations. The **contrast** adjustment can be changed to suit the users preferences. The **base level** setting determines the elevation above which the topography is displayed--a kind of "water level." After selecting another contrast or base level, simply press the **replot** button to redraw the screen. The cursor shows the horizontal (x), 3D position (y), and elevation (z) for any point it passes over. Finally the Erupt-3D button opens the Erupt3D Viewer application.

Note that this topographic representation is calculated by a unique algorithm for each eruptive unit as it is emplaced, if the mapping option is checked. Depending upon your system's speed and resources, it may take several or more seconds to calculate the topography, and its representation may vary in quality. Also, your screen settings must be set to 16-bit color or higher to achieve the necessary level of gray-scale color.

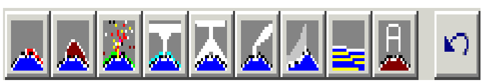
For **Erupt3 Demo** versions, a label is superimposed in the upper left-hand corner of the map. This label does not appear in retail versions. In addition, printing is disabled in demo versions.



Parameters Menu

The parameter menu allows manual selection of different eruption event types and their parameters as well as an auto mode. Upon selection of an eruption type, a parameters panel will open below the simulation window. Using this panel, the user may change various parameters that determine the nature of each eruption type. Then the program is ready to simulate.

If the user has selected the show ToolBar option, these parameter selections are displayed by the following buttons.



Principal Eruption Type Parameters

Hawaiian (Basaltic Lava Flow/Flood): Fluid type lava flows of basaltic lava that tends to pond and form shield volcanoes best typified by current eruptions in Hawaii.

Peléean (Silicic Lava Flow/Dome): Viscous lava that tends to pile up and build dome volcanoes.

Strombolian (Ballistic Fountain/Scoria Cone): Ballistic ejections of scoria and ash that form scoria (cinder) cones and ash deposits on larger composite cones. This parameter allows formation of diatremes when the strength parameter is 0.3 or less.

Plinian (Pumice and Ash Column): Plinian eruptions produce vertically driven jets and buoyant plumes of pumice and ash that rise several tens of km into the stratosphere and deposit ash over wide spread areas by simple fallout. Calderas can be formed by this eruption type when the power parameter is 0.5 or greater.

Vulcanian/Surtseyan (Pyroclastic Flow/Surge): This eruption type produces cannon-like bursts that generally form laterally moving clouds of tephra moving at hurricane speeds downslope from the vent (known as pyroclastic flows or pyroclastic surges). These eruptions build up ash and pumice deposits during explosive eruptions, often the most hazardous type of volcanic activity. Calderas can be formed by this eruption type when the power parameter is 0.6 or greater. This parameter allows formation of diatremes when the strength parameter is 0.3 or less.

Fumarolic/Phreatic (Gas Plume/No Magma): Associated with pre/post eruption activity, this eruption type involves passive steaming to infrequent steam explosions, caused by boiling groundwater near a cooling magma body (after eruption) or by the thermal increased caused by new rising magma. This activity though does not erupt magma, only pieces of older volcanic rock that is generally altered to clay-like material by the action of steam.

Tectonic Parameters

Sector Collapse (Debris Avalanche): Sector collapse eruptions involve slope failure a high-standing volcanic edifice with debris avalanche removing part of the cone and leaving an open amphitheatre-like crater. Often accompanied by Plinian activity, this activity will produce a truncated volcano.

Tectonic (Faulting/Erosion): Parameters that control tectonic events with options allowing user to simulate faulting and erosional interludes.

Program Mode Parameter

Auto: An eruption mode that produces a semi-random sequence of volcanic activities that follow shield (Hawaiian), composite cone, and silicic (caldera and domes) patterns. If Erupt is closed with Auto checked and the option 'Save settings on exit' checked, then the next time you start Erupt, it will automatically start an auto eruption sequence.

Static Eruption: Eruptions are simulated but they do not produce deposits that add to the stratigraphy. Useful as a kind of screen-saver mode.

Undo: This parameter removes the affects of the last eruption simulation, "undoing" an eruption that the user decides is not useful in a sequence of eruptions.

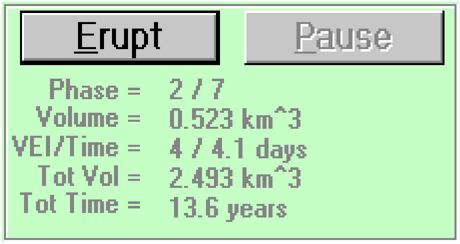
Parameters Panel

After selection of the desired eruption type from the parameters menu, a parameters panel will appear at the bottom of the ERUPT window, which allows the user to adjust various features of any given eruption/tectonic type. These features concern eruption parameters or tectonic parameters, depending upon which parameter menu item is selected. The values in these panels do not have to be changed and can be left at their default values to simplify operation.

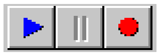
The "OK" button must be pushed in the parameters panel in order to activate the "ERUPT" button on the screen.

Erupt Button

This button (located at the bottom right of the Erupt window) starts an eruption or tectonic event when it pressed. It will only be activated when appropriate erupt parameters are selected and ok is pressed in the parameters panel. The name of this button will change to "Erode" or "Fault" when tectonic parameters have been chosen, or it will display "Auto Erupt" if that mode is chosen. If playback of a recorded file or sequence is selected from the recorder menu, the button will display "Playback", which must be pressed to start the playback.

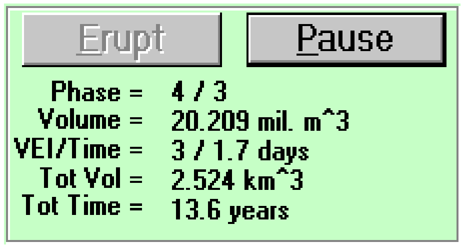


If the ToolBar is displayed (via the options menu) then the Erupt button is also shown as a blue arrowhead button.

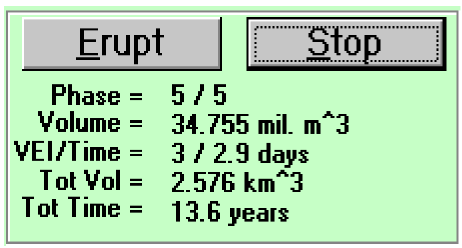


Pause/Stop Button

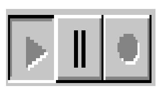
Upon pressing this button once, it will become the stop button, and the eruption will be paused, freezing the Erupt window, allowing the user to view the simulation and capture the graphics to the Windows clipboard, if the View/Capture menu item is selected. The user may continue the simulation by pressing the Erupt button or stop the simulation, by pressing the Stop button. If the eruption is stopped, the current burst will be completed and the stratigraphy is updated, and maps are completed (if enabled). The halt button will be deactivated at times when the program is inactive or busy with other commands.



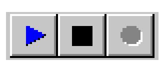
Pressing once reactivates the Erupt button for continuation and the pause button becomes the Stop button.



If the ToolBar is displayed (via the options menu) then the pause button is also shown as a button with two black vertical lines.



Pressing once:



Program Mode:

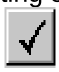
The manual mode requires the user to select for the parameters menu the type of eruption to simulate, allowing close control over the eruptive evolution of a particular volcano/volcanic field.

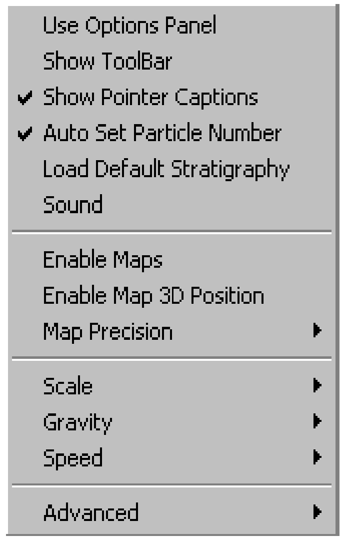
The auto mode (selected from the parameters menu) puts ERUPT into a stochastic, semi-random state where eruption parameters are automatically generated.

The static mode (selected from the options menu) shows eruptive activity but does not record the emplacement and deposition of lavas and tephra. Note that for the static mode, some of the erupt parameters are not available.

The undo parameter option removes the affects of the last simulated eruption.

Options Menu

Erupt includes a number of options for its behavior and operation. These options are selected by clicking the options menu and selecting one of the options below. If the ToolBar is displayed and options are selected by the check mark  then an options panel will displayed with selection for the following items.



General Options

Use Options Panel: Checking this option makes Erupt display an options tab panel as an alternative method of selecting options. To disable this option, uncheck it from the options panel when it is displayed, and the options menu will return to its default setting.

Show ToolBar: When checked this option displays a toolbar at the bottom of the Erupt window. It displays buttons for most common menu selections, that make for more convenient menu selections.

Show Help Tips: Checked be default, this option allows helpful hints to be displayed with the cursor.

Auto Set Particle Number: This option is checked by default. It makes Erupt automatically set the number of particles to display for each explosive eruption type depending upon the strength (or Heim Coefficient) selected. This causes eruptions of greater strength to deposit more tephra in a logical manner. The user may override this setting by manually changing the particle number after setting the strength (or Heim Coefficient) parameter. Alternatively, by unchecking this option, the particle number will always reflect the users last changes.

Load Default Topography: When checked, the default stratigraphic file (Erupt3.str) will be immediately loaded (starting a new eruption simulation) and every time Erupt is started or when file/new is chosen. When this option is unchecked the next time Erupt is started or when file/new is chosen, the default stratigraphic file will not be loaded.

Sound: ERUPT will determine if your system has a sound device. If so the sounds are enabled by default. Unchecking this option will make your eruptions silent. You may add your own custom sounds by substituting wave (.wav) files in the application's directory. Note: an option for changing the sound volume and testing the sound is available in the options tab panel. If the sound option is unavailable (grayed) or no sounds are heard when the option is checked, see trouble shooting.

Mapping Options

Enable Maps: With the enable maps option selected, the map and topography items will be activated in the View menu and the Erupt 3D Vent Positioning window will be displayed. Note by selecting this item, there will be a slight delay after completion of each eruption cycle while the map is updated.

Enable Map 3D Position: An option available when Enable Maps is checked, it activates the advanced parameter that allows positioning the vent nearer the top or bottom of the map window. This option is recommended only for advanced users. If chosen, the vent 3D position will be set randomly by the program unless the user opens the advanced parameters panel and closes it with the "OK" button, which sets the position to that indicated by the position slider.

Map Precision: An option available when Enable Maps is checked, this option provides choices of normal, high, or low determine the detail displayed for maps and topography. A high precision takes longer and low precision shorter times for map updating.

Scale, Gravity, and Speed Options

Scale: The Scale option allows the user to change the view scale of the ERUPT window. Normal shows a horizontal width of 25.6 km, large a width of 50.8, and small a width of 5.3 km. This option will redraw the screen; if a smaller scale is chosen, the user will be prompted for which part of the screen to zoom in on, portions of the stratigraphy outside the zoomed window will be removed. If a larger scale is chosen after zooming then the left and right side of the cross section will appear to be truncated.

Gravity: Allows user to adjust the gravitational acceleration that determines the trajectory of tephra.

Speed: Sets the speed at which simulations are displayed. The effect of the "fast", "normal", and "slow" settings depends upon the capabilities of the user's computer. See the topic on speed for further discussion and explanation of the "calibrate" option.

Advanced Options

Auto Update Notification: When this option is checked and an internet connection is active, the program will automatically check for version updates when you start Erupt3.

Passive FTP: This options (checked by default) sets communications protocol for registration, updates, and comments to a "passive" mode, which is required by some internet firewalls.

Save Settings: When checked, the various options and settings chosen are saved so that they will be automatically set the next time Erupt is started. In cases where various scales have been used, mapping options changed, and other particular settings have been varied for specific simulation requirements, the user may wish to un-check this option, so that more normal startup settings are retained.

Stratigraphic File (*.str, *.top):

Erupt saves and reads topographic files denoted by the extension ".str" (also ".top" from earlier versions of Erupt). These files record the stratigraphy, topography, and scale of an Erupt session at the point when the file is saved. By saving such a file, the user may open it at a future time and continue building the volcano or volcanic field. Unlike record files, topographic files are much smaller, but they do not contain information on the various combinations of parameters that were used to build the volcano or volcanic field.

A useful topographic file provided with Erupt is call "Erupt3.str". This file consists of a series of horizontal beds that might represent a sedimentary platform upon which a volcano can be built. By checking the option "Load Default Stratigraphy", each time the program is started or a new file (file/new) is chosen, Erupt3.str will be loaded. This feature is convenient for developing a tectonic structure (by faulting) upon which to build a volcano. It is also convenient for showing the crater development in areas not already underlain by volcanic products.

Digital Elevation Model (DEM)

The 3D capabilities of Erupt 3.0 include the ability to open and save digital elevation models as files with the extension ".dem". The format of this ascii (text) file is either vector or raster data.

Erupt saves a DEM file in vector format, and uses a grid-size determined by the map resolution selected under the options menu. When a DEM file created by Erupt is read in, the scale will be set to that used to create the file.

Erupt has limited ability to import DEM files for which the file extension has been set to ".dem". These files should be edited (using Notepad or Write) to have a header that signals Erupt as to whether the data are vector or raster type.

For **vector data**, vectors are read as x-y-z triplets separated by commas or tabs where x and y are map coordinates for corners of square grid (dx = dy = constant), and z is elevation (in same units as x and y). The header for vector files requires the first line to have "Vector:" This header signals Erupt that the next line begins vector data.

For **raster data**, the header should be a line starting with '$Raster:' followed by values denoting the number of rows, the number of columns, and the distance between them (e.g.," $Raster: 100, 200, 50"; where '50' denotes 50 meter intervals). Erupt will then read the next line as the start of rasterized elevation data.

If you have trouble opening a DEM file saved by another program, you may have to edit it for compatibility with Erupt (see technical support).

Erupt Recorder File (*.rec):

A special file that records all of the parameters chosen by the user and automatically set by the program during a session of Erupt simulation. The user activates recording by checking "Record Eruption History" from the "Recorder" menu or pressing the record button on the ToolBar if its option is selected. All events will be recorded until "Record Eruption History" is unchecked. If a simulation has been recorded, the user may save it as a record file from the file/save menu.

A currently recorded eruption simulation may be played back by selecting "Playback Current Eruption" from the "Recorder" menu (making sure that the "Record Eruption History" item remains checked), or by pressing the play button from the ToolBar when no parameters are checked. Alternatively, the user may open a previously recorded record file; the scale will automatically be set to that used to create the record file..

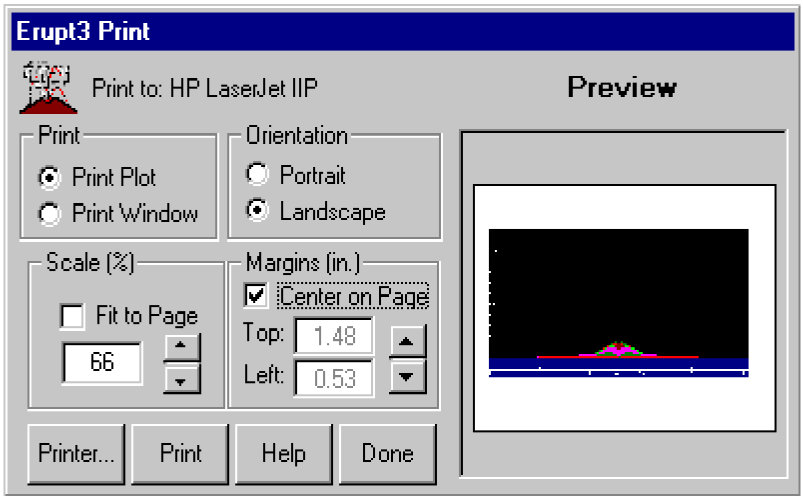
Upon opening a record file, all menu selections except the "Recorder" menu will be disabled. The user then presses the playback button to start the record, hitting the halt button at any point to stop the playback. To enable the menu items, the user must uncheck "Playback Current Eruption" from the "Recorder" menu or by un-pressing the record button on the ToolBar.

An erupt record file can be edited using the menu item "Edit Record" in the Recorder menu or by using the program EruptEdit.

Printing

Printing from Erupt is achieved by choosing print from the file menu. The print selection panel gives options to choose your printer, preview the size and placement for printing a plot, and print the entire Erupt window. Printing the map and topography window is achieved by pressing the "print" button on those windows, which will open the above selection panel.

Note, printing is disabled for the demo version.



Preview displays the how the a plot will look on the printed page. To view a larger preview, simply drag a corner of this print panel, which will automatically resize the preview window. Note that the preview is only available when the "Print Plot" option is selected.

Print plot prints a copy of the Erupt plotting window only, and it may provide the better results than the print window option. With this option a preview window is displayed to help the user to specify paper orientation, the scale of the printed graphic and the page margins.

Print window option prints all of the Erupt window, including the form and its panels, such as the legend (be sure to choose view/legend option before printing). The preview, orientation, scale, and margins settings will not be available. On some computers, though, this method might not produce results as good as the print plot option.

Options include orientation, scale, and margins. Landscape orientation is automatically chosen for Erupt printing to better suit the format of the Erupt/Map/Topo window. The scale option allows the user to choose how large the printed graphic will be on the printed page; by choosing "Fit to Page" the largest size is automatically chosen, disabling the margin adjustment option. The margins options allows the user to position the graphic on the page;by checking the "Center on Page" box the graphic is automatically centered left and right and top and bottom, disabling further adjustment of the margins.

Printer brings up the Windows print control and allows the user to specify which printer to use and its properties. If print results are not satisfactory, then try changing the printer properties such as its resolution, colors, and whether or not to print text as graphics.

Print sends the graphics to the chosen printer.

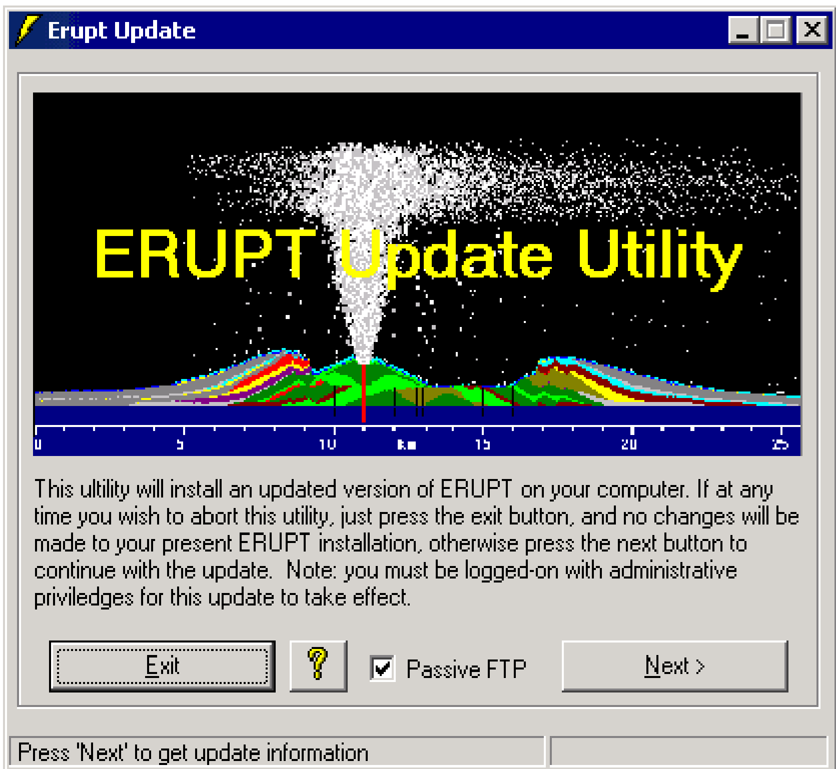
Help conveniently displays this page for quick reference.

Done must be pressed in order to return to Erupt

Erupt Update

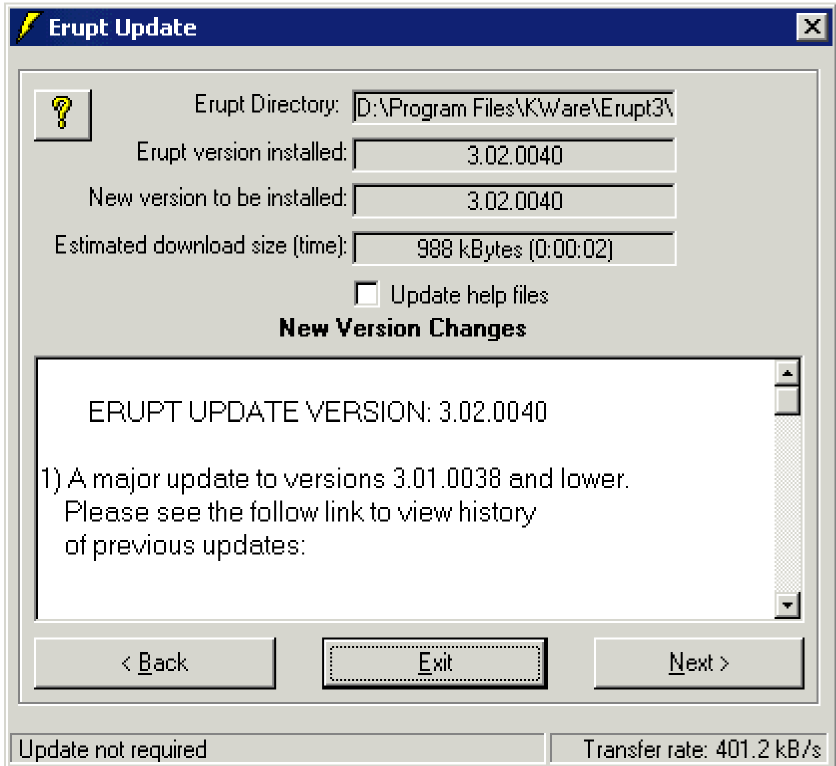
Erupt is regularly updated to add/refine the program operation and make changes that users request. Generally, registered users will be notified by email when an update is available. From the File menu, choose "Live Update" and the following window will be displayed. Alternatively, Erupt Update can be run by itself (stand alone) by clicking its icon in the Erupt3 folder in the Windows Start Menu.

Follow the Update Wizard as described below. By pressing the "Next" button, Erupt update will queery an FTP server to see if the program is current or what updates are available (an internet connection will automatically be establish if needed; if your connection uses a firewall, then checking the box "**Passive FTP**" may be required to successfully download files). If a problem with the internet connection is encountered, the user will be notified. Erupt Update can also be downloaded to your hard disk from the Erupt User page. By double-clicking the downloaded file, the Update Wizard will begin and run locally without using an FTP server.



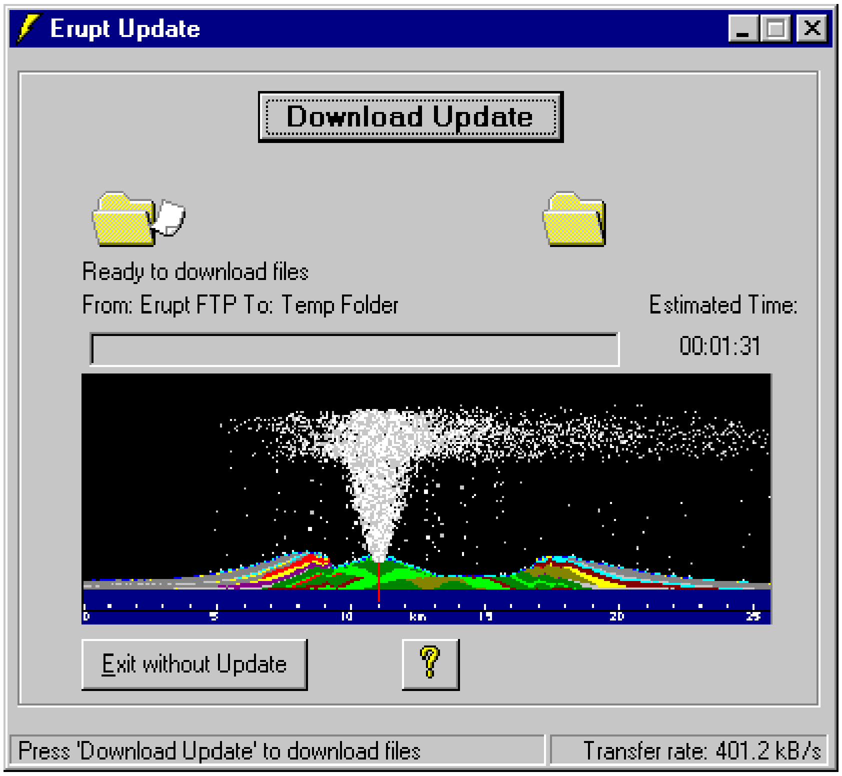
With a successful FTP connection, you will be notified if an update is available. If Update is run from the Erupt3 program and you choose to continue with an available update, then Erupt will be unloaded during the FTP download session.

The following screen will be shown, listing old and new version information and estimated download time. Because updated help files are typically large (~4 MBytes), they are not included in updating, unless you check the box labeled "**Update help files**." Note that when you check this box, there will be a temporary wait while Erupt Update gets the size of these additional files and recalculates your download time. The status bar at the bottom shows your FTP connection transfer rate will be displayed (which may vary during the download process), and based on that and the estimated download time, you can consider whether or not you want to spend the online time required or not.

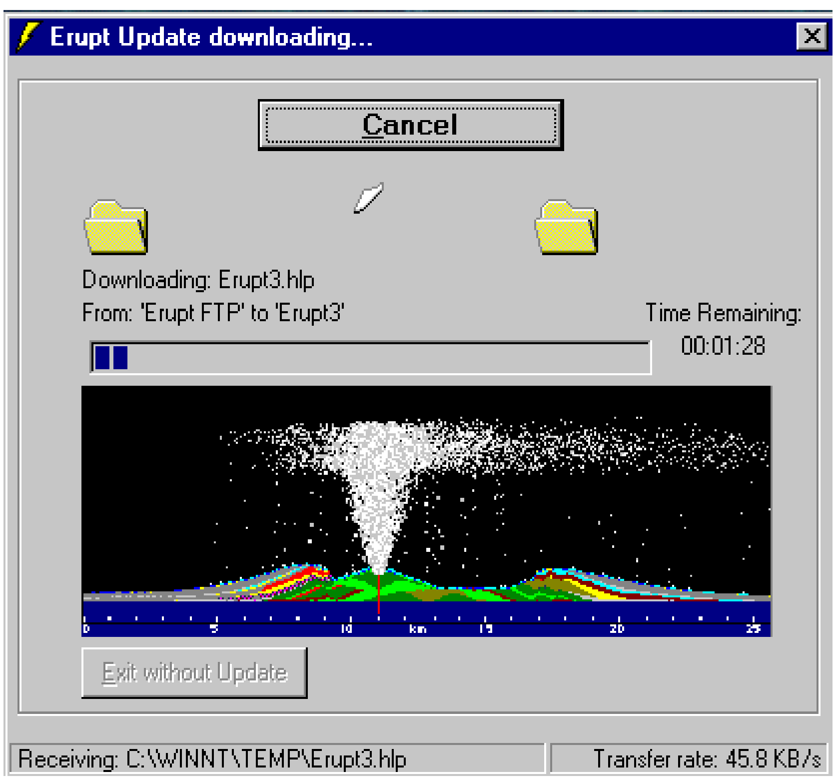


After reviewing update information and you choose to continue the update, press "Next" (this button will not be enabled if no update is available.

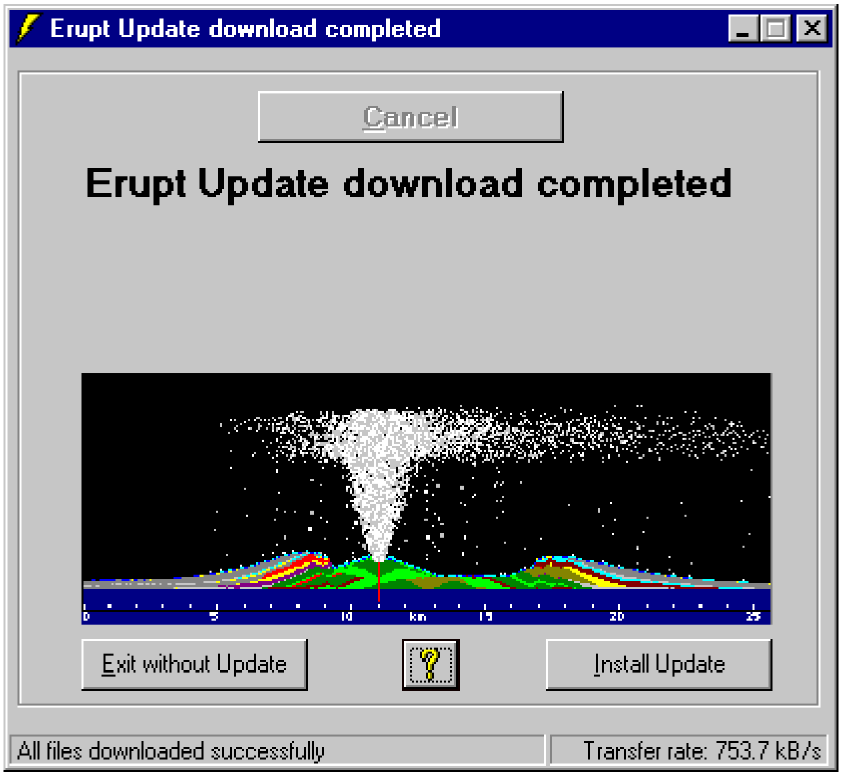
Following acceptance of the common license agreement form the following window will be displayed. The estimated download time will be displayed, but it may be faster or slower, depending upon your internet connection. Press the "Download Update" button to begin the download.



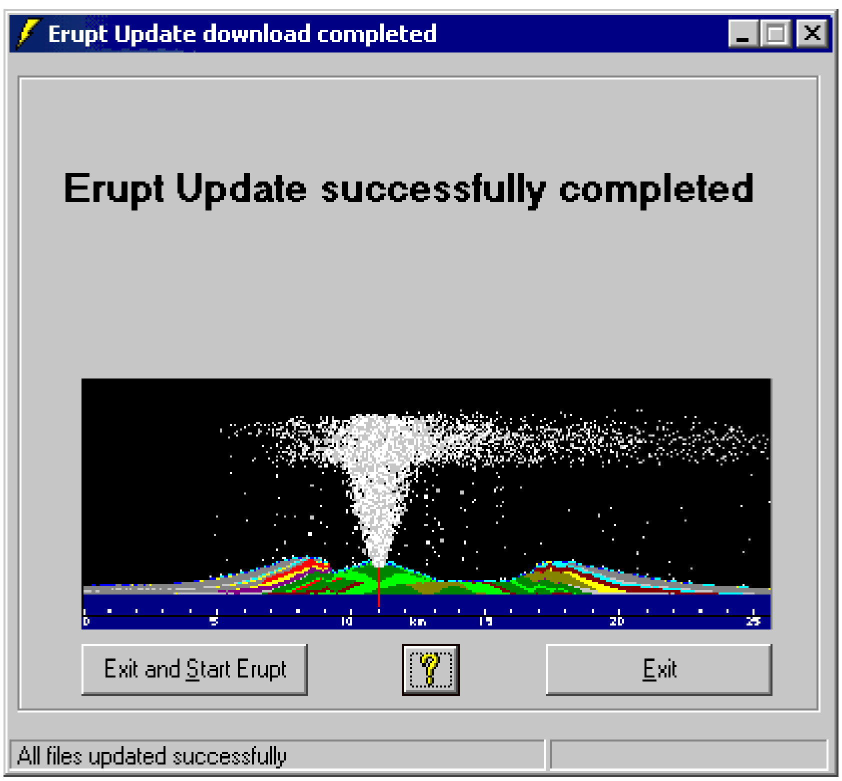
During the download, the user may choose to cancel. Note that no changes will be applied until the download is complete and the "Finish" button is clicked. If the Cancel button is clicked, the program may require some time to disconnect. Also, if unexpected internet download error(s) occur the program will notify the user.



Upon completing the update download, the user may choose to complete the update of files by pressing the "Install Update" button, or exit without the update.



Pressing the "Install Update" button reloads Erupt Update so that files can be copied. Copying might include registration of new system files and updates to the Erupt3 registry settings. After the copying is completed the following screen appears.



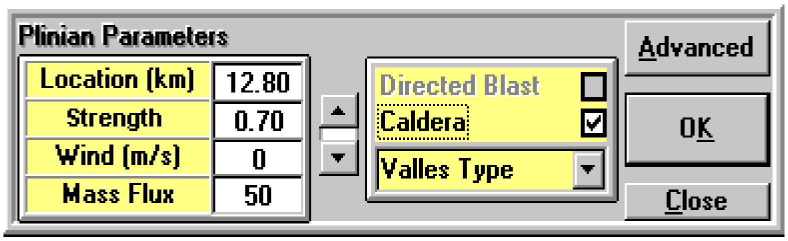
An update log file, saved in the folder where Erupt3 is installed, can be viewed with any text viewer (such as Notepad), and it shows the results of the update. The user has a choice of exiting Erupt Update, or exiting and starting Erupt3. Note that after an update, the user will be required to resend registration information.

Eruption Parameters Panel

Rather than presenting the user with a complex set of physical variables, such as temperature, pressure, volatile content, magma composition, mass eruption rate, and velocity, Erupt parameterizes the effects of these variables into more intuitive selections. By changing these parameter selections, which vary depending upon the type of eruption selection, the user can simulate practically any eruptive phenomena that is allowed by what is known of eruption physics.

After selecting an eruption type from the parameters menu, an eruption parameter panel will be displayed at the bottom of the Erupt window. The user may change the following parameters (depending on the type of eruption selected), or the user may just accept the default values shown. To change the parameter, simply type in new values, or click on the parameter to change and use the arrows to increase or decrease the value. For changing the vent location parameter, a simple method is described below.

To proceed with an eruption and activate the Erupt button, the user must press the "OK" button in the eruption parameter panel.



- Primary Parameters   - Secondary Parameters

Primary Parameters

Location: Position in km along the horizontal scale for the new vent that will be created. As this parameter is changed, a gray cursor will move across the screen above the horizontal scale to show the position. A simple method for changing this parameter involves clicking on the desired position in the simulation window or, if the "Enable Maps" option is checked, by using the Erupt 3D Vent Position window.

Strength: Scale (0.1 to 1) of relative strength or energy hence column height for Plinian and Strombolian type eruptions. For some explosive eruptions, setting this parameter will change the default mass flux simulated. For Vulcanian/Surtseyan eruptions, the strength value is used by Erupt to compute a "Heim Coefficient", which is a measure of runout mobility for pyroclastic flow/surge and sector collapse eruptions. Higher the values produce shorter the runout and smaller craters.

Wind: Wind velocity in m/s to the right (positive) or left (negative) directions.

Mass Flux: The eruption discharge rate is proportional to the number of representative marker particles for Plinian, Strombolian, Vulcanian/Surtseyan, and Fumarolic/Phreatic eruptions. A default value will be assigned based on the strength selected, but this number can be changed to suit the user's needs.

Secondary Parameters

Directed Blast: A check box to designate whether a pyroclastic flow/surge will dominantly runout in the direction of lowest topography around the vent.

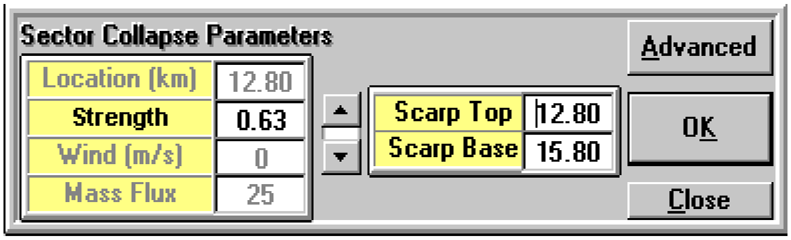
Explosive Bursts: A check box for specifying that Fumarolic/Phreatic eruptions are punctuated by explosions.

Caldera: A check box that determines whether a Vulcanian/Surtseyan or Plinian eruption forms a caldera collapse event. This parameter is only available for eruptions of sufficient strength.

Diatreme: A special option for Strombolian and Vulcanian/Surtseyan type eruptions of strength less than 0.3, respectively, which simulates the emplacement of a diatreme below the vent.

Caldera Type: Select either "Mazama" or "Valles" type; the former type is that associated with composite cones and the latter to volcanic fields.

Scarp Top and Base: For sector collapse eruptions only, select the locations of the collapse scarp top and the base of the volcanic edifice in the direction of desired runout. Note that the top and/or base location must be different in order for the 'OK' to be enabled. As this parameter is changed, a gray cursor will move across the screen above the horizontal scale to show the position. Clicking the simulation window at a desired location will alternatively set the scarp top or base.



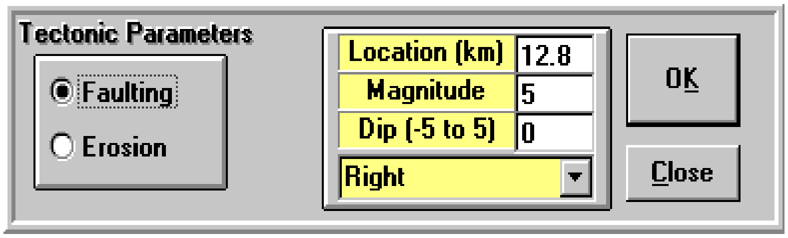
Advanced Parameters

Advanced Parameter Options: Allows specification of lava flow length, crater diameter, strength growth, speed adjustment, and if Maps enabled, allows specification of 3d position of the vent.

Tectonic Parameters Panel

After selecting "Tectonic" from the parameters menu, an tectonic parameter panel will be displayed at the bottom of the Erupt window. The user may change the following parameters (depending on the type of eruption selected), or the user may just accept the default values shown.

To proceed with a tectonic event and activate the Fault/Erode button, the user must press the "OK" button in the tectonic parameter panel.



Choose either erosion or faulting event. For faults you have these options:

Location: The position in km for the top of the fault scarp.The user may choose the fault scarp top by simply clicking on the desired position in the simulation window.

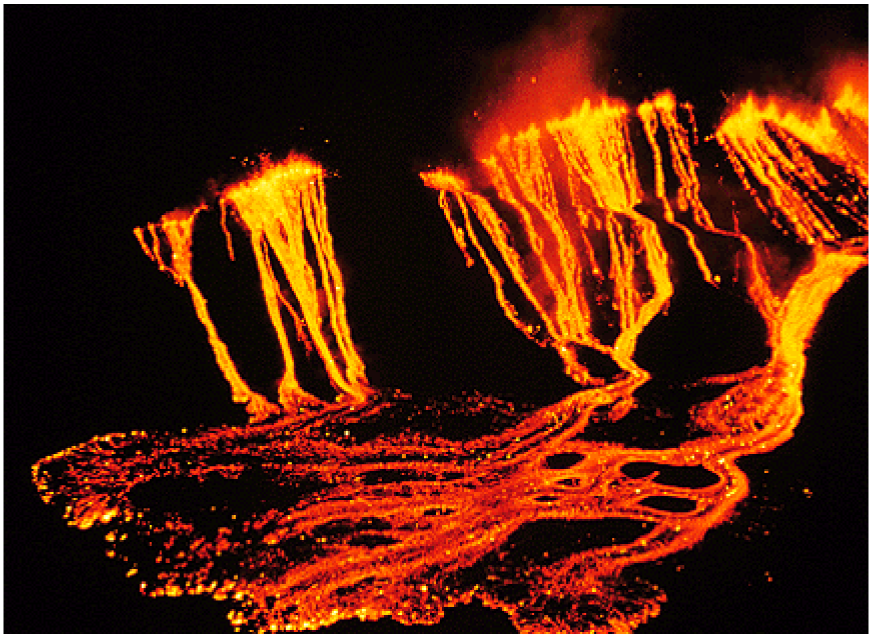
Magnitude: Scale 1 to 10 degree of movement, 10 being largest.

Dip: Scale -5 to 5; dip decreases with number, negative values for dips to the left, positive for dips to the right. Vertical is 0 for which you must choose the downdropped side.

Down Side: Choose either left or right for the downdropped side.

Hawaiian eruption:

This type of eruption is typical of lava flow activity in Hawaii. Consisting of fluid basaltic material that is erupted red hot, the lava tends to form thin flow, to pond in low areas, and over time forms shield volcano.



Hawaiian eruption of basaltic lava from Kilauea Iki in 1959.

Peléean Eruption:

Named after the 1902 eruptions of Mont Pelée in Martinique, this eruption type involves growth of lava domes and spires accompanied by explosive blasts giving rise to Nuees Ardentes (pyroclastic flows). For the Erupt program, Peléean eruption simulates the dome growth phases composed of silicic lava flows, and the user may select Vulcanian parameters for the explosive phases.

Unzen volcano, Japan is in a quiet phase of Peléean dome growth activity.

Strombolian eruption:

Strombolian eruptions are ballistic ejections of scoria and ash that form scoria (cinder) cones and ash deposits on larger composite cones. A good example of this activity today is the volcano Stromboli in Italy, and a well documented case is Paricutin volcano in Mexico.

Diatreme eruptions are a special case where Strombolian (or pyroclastic surge) activity form a deep conduit filled with breccia. After erosional periods, diatreme conduits are volcanic necks that often are distinct positive relief features.

An eruption at the volcano Stromboli.

Plinian eruption:

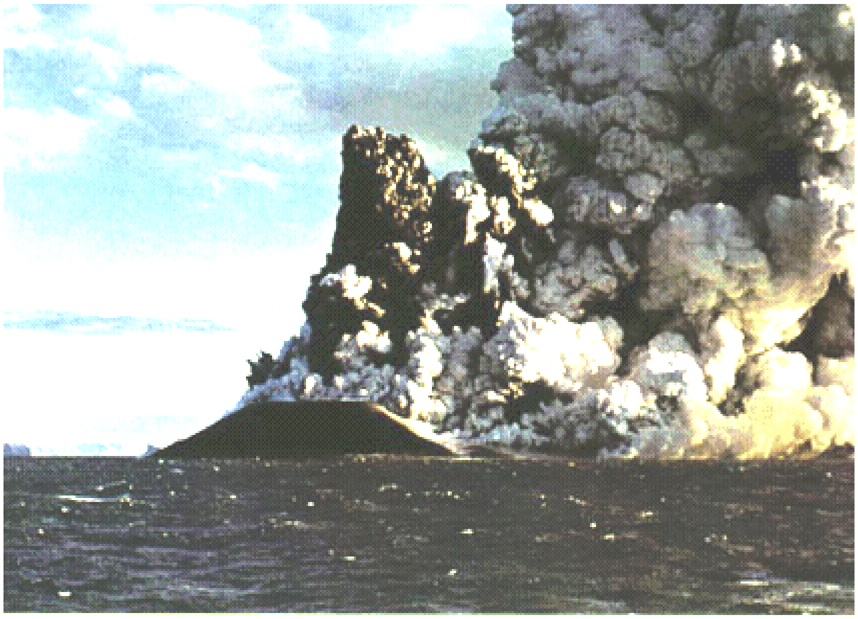
Plinian eruptions are named after Pliny the Elder who described the AD 79 eruptions of Vesuvius. These eruptions produce vertically driven jets of pumice and ash that rise several tens of km into the stratosphere, forming a high standing eruption column, commonly with an anvil-shaped top, and deposit ash over wide spread areas by simple fallout.

The May 18, 1980 Plinian eruption of Mount St. Helens.

Vulcanian/Surtseyan Eruption:

Named after the grandfather volcano on the island of Vulcano, just north of Sicily, this type of eruption consisting of the explosive ejection of incandescent fragments of new viscous lava, usually on the form of blocks. For the Erupt program, this eruption type encompasses all explosive activity that produces pyroclastic flows and surges, resulting in crater excavation and distribution of wide-spread tephra. Caldera collapse may occur during the largest of these eruptions, whereas smaller Surtseyan eruptions may produce maar craters tuff rings and cones.

Vulcanian eruption producing a pyroclastic flow.



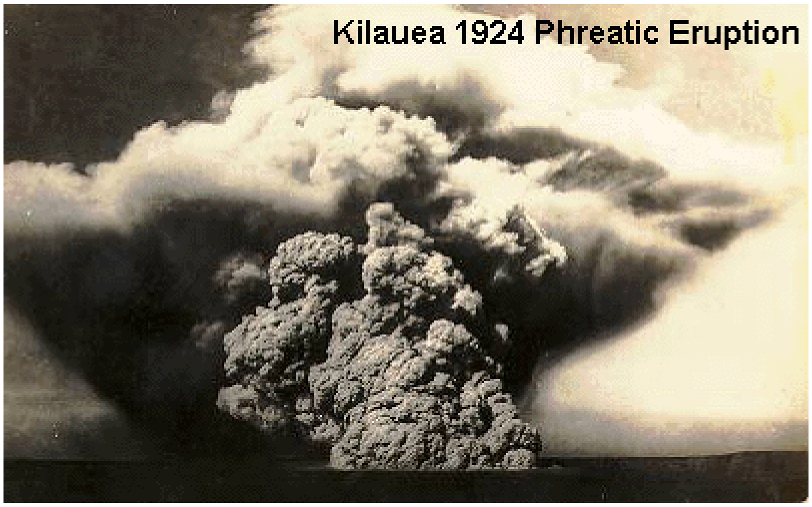
Eruption of Surtsey in 1965 produces jets of steam and tephra that form a column that collapse down to form a pyroclastic surge.

Fumarolic/Phreatic Eruption

This volcanic activity is generally passive and does not erupt magma. Residual heat in a volcano boils groundwater which emanates from an inactive crater or fissures surrounding the volcano. If the steam rise is vigorous enough, it can carry along small fragments of altered rock of ash size.

Fumarolic eruption at Santiaguito volcano, Guatemala

Periodically, fumarolic activity may become explosive (known as phreatic eruption), producing short-lived blasts of steam, ash, and blocks, the solid material coming from rocks in the volcano blown out by the explosive release of high-pressure steam.



Sector Collapse:

When the flanks of a high-standing volcano (e.g., composite cone or dome) become unstable, a portion or sector of the volcano may break loose and slide down hill as an avalanche. Such behavior is often triggered by an earthquake and/or by magma rising under a volcano. When a sector collapse occurs, a debris avalanche is initiated and the summit of the volcano is truncated, often forming an amphitheatre-like depression in the volcano.

Mount St. Helens after its May 18, 1980 eruptions cause a sector collapse.

Tectonic Events:

Tectonic events for ERUPT include various types of normal faulting events with user selected offset (magnitude), dip, and location. Erosion intervals may also be specified by this parameter selection

Auto Eruption

This eruption parameter puts the program in an automatic mode where eruptions progress from one type to another in a stochastic fashion after the user presses the erupt button. The sequences of eruption types, parameters, vent locations follow a semi-random order that tends to follow shield building, composite cone, dome building, and other typical volcano evolution patterns. Using the program in this mode is often instructive, teaching volcano novice about the cyclic nature of volcanism, and typical patterns of volcano/volcanic field evolution.

If Erupt is closed with Auto checked, then the next time you start Erupt, it will automatically start an auto eruption sequence.

Sounds

Erupt comes with many predefined sounds. If the sound option is enabled, the sounds play continuously in a "loop" during a given eruption simulation. Under certain circumstances, sounds will not play, or loop, or the volume control in the options panel will not work. In these cases see technical support.

These sounds are contained in "*.wav" files (e.g., Erode.wav) in the "Sounds" subdirectory or your Erupt directory (*e.g.*, C:\Program Files\Erupt 3.0\Sounds). These wave files can be edited (using a sound file editor such as "Sound Recorder", provided with Windows) or they can be substituted with others the user prefers, but in doing so, the same name for each file must be retained.

The following files should exist.

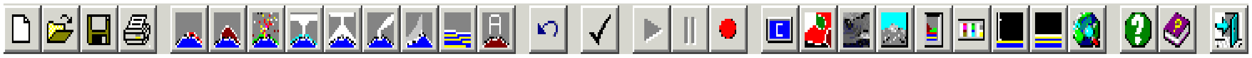
Surge.wav
Collapse.wav
Dikecool.wav
Dikeint.wav
Dome.wav
Erode.wav
Fault.wav
Fumarole.wav
Lava.wav
Off.wav
Opening.wav
Stromb.wav
Closing.wav
Plinian.wav

The sounds may be disabled if the user prefers silent simulations by unchecking the sound option in the options menu.

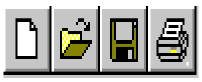
If the sound option is checked and no sounds are heard, first check to see if your sound driver is properly installed, the "wave out" device is enabled, and the volume settings are correct in your Windows volume control applet. If these settings work, and sound normally functions correctly for your computer see trouble shooting.

ToolBar

The Erupt toolbar (shown below) is displayed when the option "Show ToolBar" is selected. It displays a panel of buttons, some of which may be disabled, depending on program options selected. The first time the ToolBar is shown, all available buttons are displayed. If the buttons run off the right edge of the main Erupt window, resize the window to show them all. The ToolBar can be customized by double-clicking on blank spaces between groups of buttons. Customization allows rearranging, adding, or removing buttons as the user desires. The arrangement will be saved for future sessions. To restore all available buttons to the toolbar, press the "reset" button while the customization window is open.



From left to right the buttons correspond to:

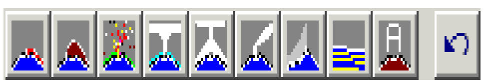
File: 

new - starts a new simulation

open - displays file open options

save - displays file save options

print - displays print options

Parameters: 

Hawaiian

Peléean

Strombolian

Plinian

Vulcanian/Surtseyan

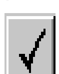
Fumarolic/Phreatic

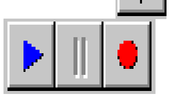
Sector Collapse

Tectonic

Auto

Undo: This parameter removes the affects of the last eruption simulation

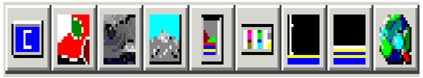
Options (check button):  All options are displayed in an options tab panel

Erupt Buttons: 

Erupt simulation start/playback: this button has the same function as the Erupt button. Playback starts only when the record button is pushed (inset) and an eruption record is available. If after the user records/plays a record and then un-pushes the record button, playback is disabled and the button returns to normal erupt function.

Pause/Stop button: this button has the same function as the Pause/Stop button.

Record button: Enabled recording eruption cycles and later playback.

View Buttons: 

Capture

Map

Topography

Erupt-3D View

Stratigraphy

Legend

Vertical Scale: This view option shows a vertical scale on the left side of the erupt window.

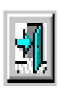
Refresh: Re-draws the screen if it has been corrupted by another application

Erupt WWW Browser: This selection opens the system's internet browser to the Erupt User's page.

Help Buttons: 

Toolbar help

Help contents

Exit: 

Options Panel:

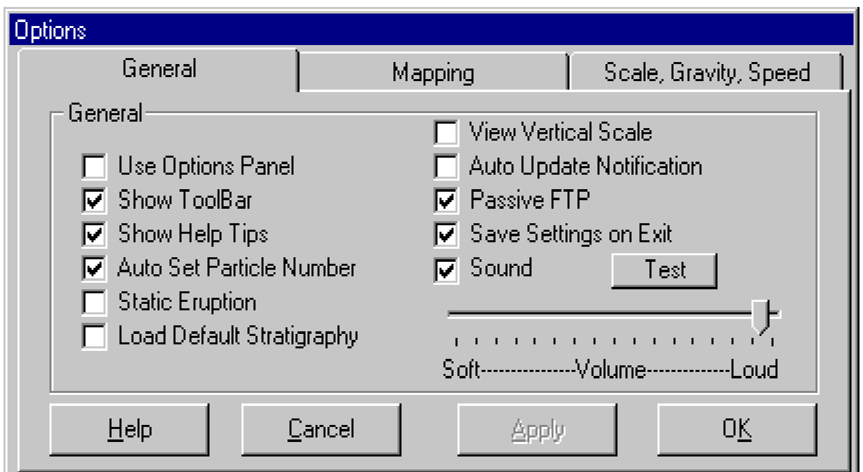
The options tab panel is available by clicking "Use Options Panel" under the options menu.

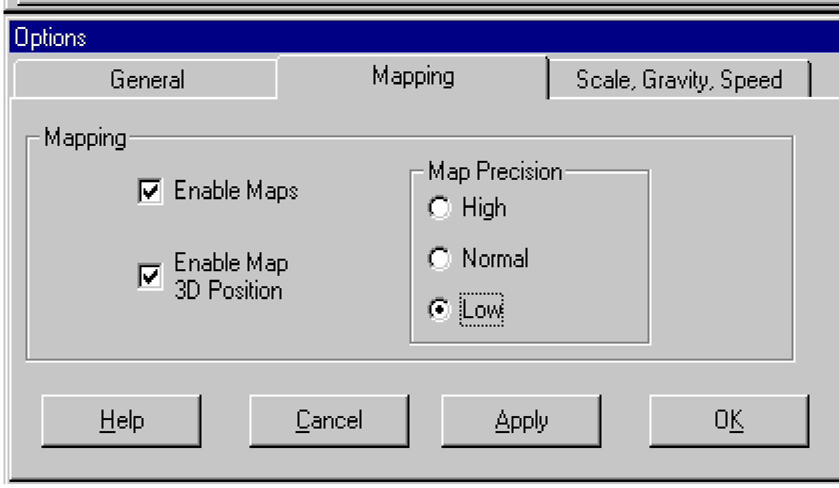
Three tabs present three groups of options: General, Mapping, and Scale, Gravity, Speed.

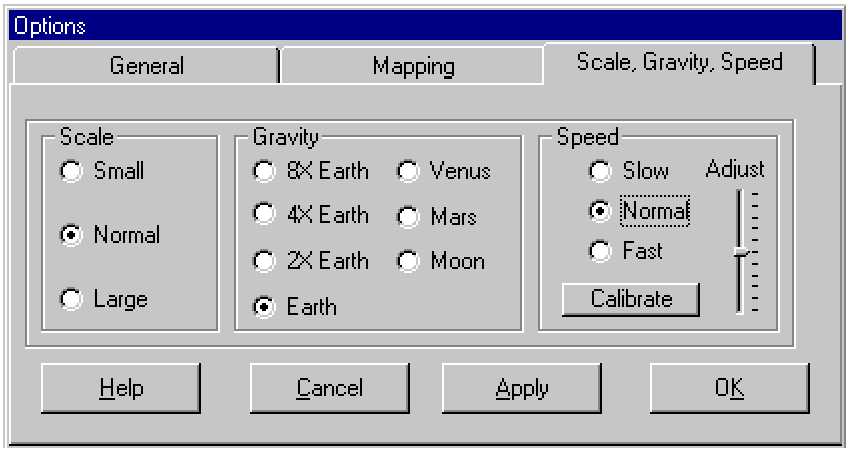
After selecting options, the user may press the apply button (disabled until an option is changed) to invoke the option immediately, or choose cancel to return to the Erupt window without changes, or select OK to invoke any options change and return to the Erupt window. These options are described in the options menu help.

General options provide two settings not available under the options menu: sound volume and test. Both settings are available when the sound option is checked. The volume slider will show the current "wave" volume setting for the system. Moving the slider changes the systems wave volume and will make Erupt sounds louder or softer, depending on the direction the slider is moved. The user may test the sound volume by pressing the "Test" button. An Erupt sound will be played until the button, now labeled "Finish" is pressed. During a test the user can adjust the volume to a desired level. If no sounds are heard when the sound option is checked, or the sound does not play continuously (loop) during a test, or the sound options are grayed and unavailable to change, or the volume slider produces no effects, see trouble shooting.

Speed options include a slider for adjusting the simulation speed, which is identical to the "slow-fast" adjustment available in the advanced parameters panel.






Options
General
Mapping
Scale, Gravity, Speed
Scale
Small
Normal
Large
Gravity
8X Earth
4X Earth
2X Earth
Earth
Venus
Mars
Moon
Speed
Slow
Normal
Fast
Adjust
Calibrate
Help
Cancel
Apply
OK

Mapping

Erupt produces pseudo 3D geologic and topographic maps by a translation algorithm that renders the 2D stratigraphy and elevation data in a plan view. This option can be activated by checking "enable maps" in the options menu. Considering the stratigraphic profile as x and z (width and height) data, the y data is generated by a complex series of calculations that compute the distribution of eruption products in that dimension. In addition, if the option Enable Map 3D Position is checked the the user may specify the y location of the vent in the advanced parameters panel or the Erupt 3D Vent Position window; if not specified a random y-vent position will be selected. Otherwise, if the Enable Map 3D Position option is not checked, then vent position is placed at the vertical center of the map

Overall, this feature is useful for teaching the relationship of plan view to elevation views of geologic map data. With careful application, maps can closely approximate real-world volcanic map and morphology information in 3D.

Scale:

Erupt simulates eruptions in a window with a horizontal scale bar for reference. Three different scales are provided: small (5 km wide), normal (25 km wide), and large (125 km wide). The user selects the scale with the options menu or ToolBar button. A small scale is useful for simulating single small volcanoes, the normal scale provides room for a number of vents such as a small volcanic field or large composite cones, and the large scale is useful for large volcanic fields and calderas. The view menu also can be selected to display a vertical scale bar, which changes with changing the simulation window scale.

Note: These scales only give an approximate idea of horizontal/vertical distances. Some exaggeration of vertical relief is necessary to portray thin layers of lava/tephra. When saving a stratigraphic file, the scale option will be saved also, so that upon opening a saved file, the simulation window will be set to the scale used during creation of the file.

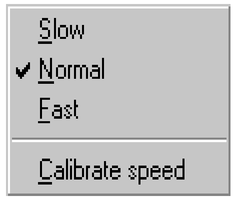
When the option scale is chosen the user may change the plot window scale to small, normal, or large. When going to a smaller scale (such as from normal to small), the user will be prompted to specify which part of the window to zoom in on (such as left, left center, center, right center, or right). That portion of the window will be shown and stratigraphic information falling outside of it to the left or right will be lost. The new scale will be shown, and for the case of small scale, parameters will be automatically adjusted for the smaller scale, and finer volcanic features will be available.

When choosing a larger scale, the present stratigraphy will be compressed to fill in only that portion of the new window that contains the previous scale coordinates. The stratigraphy will appear truncated where product distribution has not been computed on the left and right sides.

Note that when changing scale, map data will be lost, because the superposition of new eruption products of one scale on a map produced at another scale would be erroneous.

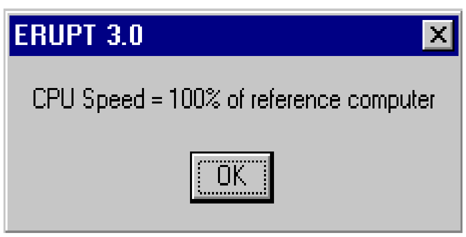
Speed

Three program speed options are available in Erupt: slow, normal, and fast. In addition there is an option to calibrate the speed to your computer's CPU.



These speeds determine how fast simulations are displayed on the screen. For explosive eruptions, the speed option will increase or decrease the default number of particles simulated, depending on the strength/Heim Coefficient parameter chosen (this value may be over-ridden by the user by adjusting the number of particles after choosing the strength/Heim Coefficient parameter). While the fast speed option allows the user to quickly build a volcano, if auto mode is also chosen, the number of particles portrayed will be automatically limited depending on the user's computer speed. The slow speed option allows the user to see more detail during an eruption (more simulated particles). The normal speed option is best suited for most applications. The effect of the speed option can be varied by adjusting the Slow/Fast slider in the advanced parameters panel and in the options tab panel.

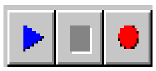
When Erupt starts it calibrates these speeds to your computer's CPU's performance. With time the CPU's performance may change, depending on the number of applications running. The user many then wish to click on this option (or the calibrate button in the options tab panel) to recalibrate the speed factor, which will cause a message to display your current Erupt system speed compared to that of a reference computer. Your computer's speed may be greater (>100%) or less (<100%) than that of a reference computer; this speed is only relative.



If your simulation speed seems to running more slowly than usual, then first check that the menu item "Capture" is not checked under the View menu, then if that does not seem to help, close other programs that are running in the background.

Record Menu

The record menu options are new for ERUPT 3.0. Selecting "**Record Eruption History**" (or by pressing the record button on the ToolBar) makes ERUPT remember each eruptive cycle and its behavior. Selecting "**Playback Record**" is only possible after recording one or more eruption cycles or after opening an record file.

 The record button on the ToolBar is shown by a red circle and the playback button is shown by the blue arrowhead.

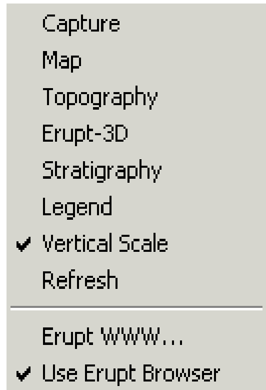
After recording eruption events, choose playback record and then press the "Playback" button on the bottom of the Erupt window, which will cause the program to replay all the cycles that have been recorded, after which new eruptions can be recorded. If the menu item '**Loop**' is checked, the playback loops continuously through the record sequence until the pause button is pushed.

After playback, the playback option must be unchecked in the Record menu or un-pressed on the ToolBar in order to record more ERUPT cycles.

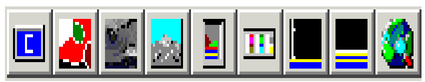
A record file may be saved to be replayed later by choosing save/record from the file menu. It may also be edited by selecting 'Edit Record'.

View Menu

The view menu is new for ERUPT 3.0. New items include viewing geological maps, topography, and detailed stratigraphy for a volcano or volcanic field. These views are windows superimposed on the main Erupt window.



If the user has selected the show ToolBar option, these view selections are displayed by the following buttons.



From left to right the button are described below:

Capture: This option sets a mode that when an eruption is paused, the graphics displayed are copied to the Windows Clipboard, for pasting into other applications, and the user is given the option to print the graphic. Updated in version 3.01.0030, older version of this option caused the eruption to proceed very slowly, capturing every particle as it moved, but the new version does not affect the simulation speed.To 'capture' an eruption in progress, press the pause button at a time when you want a picture, Erupt will notify you that an image has been saved and that you may print it immediately.

Map: Only available when the option "Enable Maps" is chosen, selecting this item will bring up the geologic map window that displays a plan view, geological map of the volcano or volcanic field, color coded as shown in the Legend panel. Within this window, the user may select "View Topography" to bring up a topographic view.

Topography: Only available when the option "Enable Maps" is chosen, selecting this item will bring up the topographic map window that displays a topographic map of the volcano or volcanic field, with artificial sunlight illumination direction that can be chosen by options in this view. Within this window, the user may also select "View Map" to bring up the map view. Note: topographic views will only be realistic if the screen is set to display 32k colors or more. Erupt will warn you of this situation and open your Windows desktop screen settings control panel for you if you wish to change the screen settings immediately. (Note: on some systems, changing the screen settings may require a system restart).

Erupt-3D: Only available when the option "Enable Maps" is chosen, selecting this item opens the Erupt3D Viewer application that displays the topography in a fully three-dimensional layout, that allows navigation around the simulated volcanic topography like a field geologist or a remote observer in an aircraft. Users must have DirectX version 7 or higher installed in their system in order to use this viewer.

Stratigraphy: Choosing this view option, displays a detailed stratigraphic column window, which magnifies the color-coded stratigraphy at any location. Use the scroll bar to move to different locations to view lateral changes in stratigraphy.

Legend: A quick way to close Parameters panel and show the stratigraphic legend

Vertical Scale: This is a view option that when checked shows a vertical scale on the left side of the erupt window. Unchecking this view option removes the scale. The scale must be considered as only an approximate measure.

Refresh: Re-draws the screen if it has been corrupted by another application.

Erupt WWW: This selection opens the system's internet browser to the Erupt User's page. This page provides information about program updates (available to registered users), tips and frequently asked questions (FAQs), interesting eruption files offered by users, volcano links, and other useful information.

Use Erupt Browser: This is a browser option that is available if your system supports Erupt's own internet browser. When it is checked, Erupt's browser will be used; unchecked, Erupt will use your system's default browser.

Capture

An image is automatically copied to the Windows Clipboard after the Erupt window is refreshed (at the end of each eruptive phase). The same is true for the Map, Topography, and Detailed Stratigraphy windows, when the user presses the "Copy" button. This action makes Erupt graphics available to be pasted into other applications, such as a Word document or other graphics application.

Capture: When this menu item is checked, the contents of the Erupt window are continuously updated to be available for the Windows Clipboard. If the user desires to 'capture' an eruption in progress, select this menu (or toolbar) item. During the eruption a graphical copy is made whenever the Pause button is pressed at which point the user is notified and in versions prior to 3.01.0030 and later given the option to immediately print the graphics.

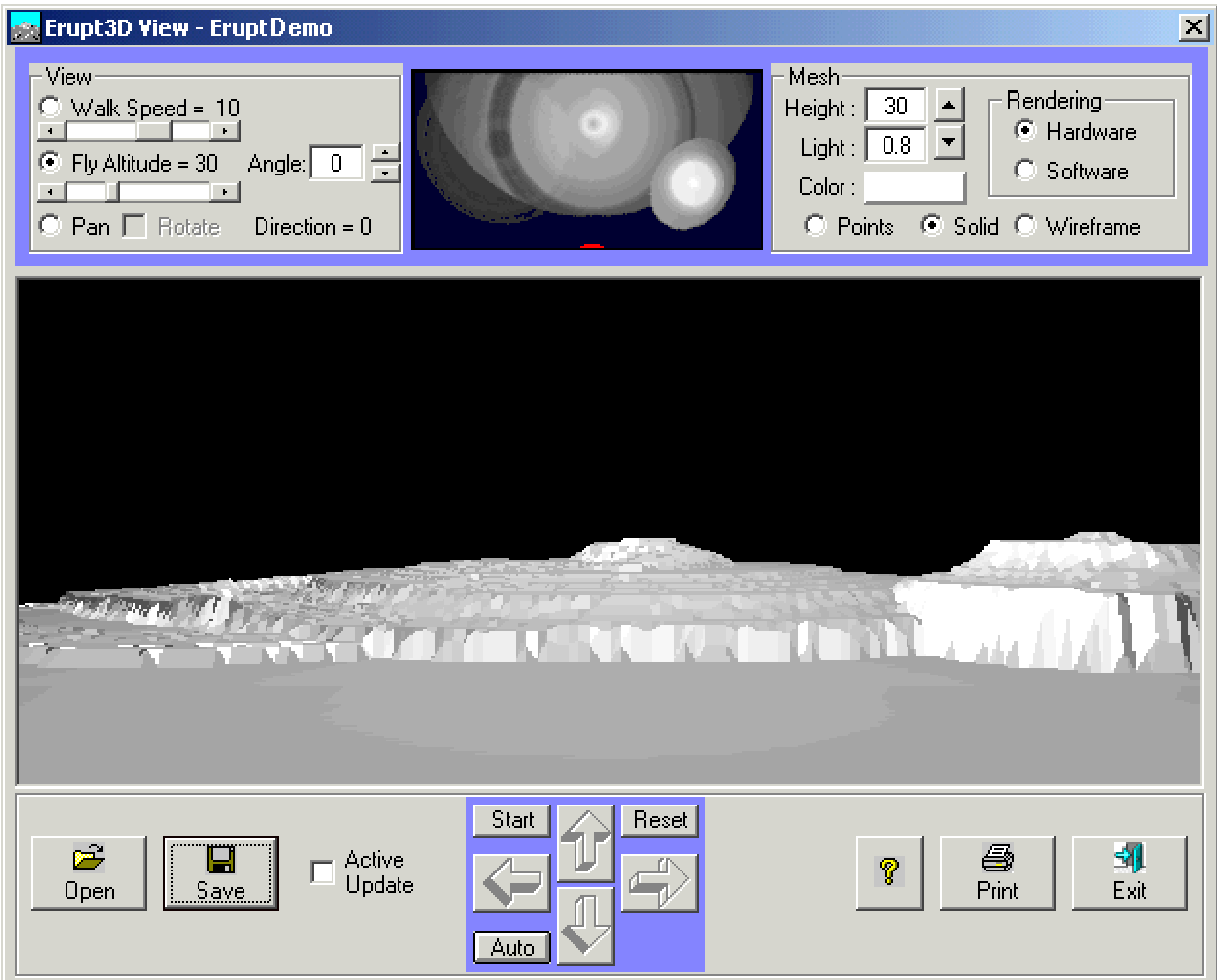
Note: Selecting this view option in older Erupt versions caused some eruptions to proceed very slowly during simulation. With prior to 3.01.0030 this slowdown hase been remedied.

Windows Clipboard: Once an Erupt graphic is copied to the clipboard, it is available to be pasted into any graphics application. When capturing an active eruption by pressing the "Pause/Stop" button, be sure to paste the clipboard image into another application before stopping the eruption, otherwise the clipboard contents will revert to the stratigraphic image only. For example, open Windows Paint application and select 'edit/paste', Then continue with the eruption.

Erupt3D Viewer

(Special thanks to Simon Price for help with the 3D code)

An added feature for Erupt3 is the Erupt3D Viewer, which utilizes DirectX 3D rendering in hardware or in software emulation. (Note: the user must have DirectX version 7 or higher to use this feature). The veiwer allows the user to view topography from any angle and to "fly" or "walk" over it, revealing much of the intricate details simulated by Erupt3. The picture below shows the viewer window. It consists of control panels, a map or plan view of the topography, and the 3D view. This viewer can be one of the funnest parts of Erupt3, providing an action arcade game-like environment (but no shooting, monsters, or alien craft).



Start the Erupt3D Viewer from Erupt either by choosing (1) "Erupt 3D Viewer" from the File menu or (2) by selecting "Erupt-3D" from the View menu or from the Erupt Toolbar (only enabled after a map has been created). When started from the File menu, the user may open any saved Erupt topographic image (or for that matter any "BMP" format graphics file which has dimensions less than 180x180 pixels) to view a 3D rendering. When started from the View menu or Toolbar, the viewer will immediately load the current topogrphic image that erupt has created

When checked the **Active Update** check box will check every 10 seconds for a newly created topographic image from Erupt and update the view display, even if a saved file is currently being displayed. Active

Update is checked by default when starting Erupt3D Viewer from the View menu or Toolbar.

The **View control** panel in the upper left allows the user to select three different viewing modes: (1) Walk--places you at ground level so that as you use the direction arrows at the bottom, you experience climbing up, down, and across the topography; (2) Fly--simulates movement across a volcanic field in an aircraft; and (3) Pan--rotates the view around an axis. The speed, height above groung (except for Walk), and the vertical view angle can all be adjusted

The **Mesh control** panel in the upper right controls the 3D rendering of the topography. Software rendering is the default, but hardware rendering may be a bit faster but it may not be supported well by your graphics board. The height and Light values determine the topographic exaggeration and brightness of the view. These options can only be selected if the rendering is stopped (the start button is showing at the bottom). The user must reload the topography by either using the "Open" button in the lower right corner or by simply double-clicking the small map view picture. The color button instantly changes the color of shading in the 3D view, and the "Points", "Solid" (Default), and "Mesh" options will instantly change the display mode.

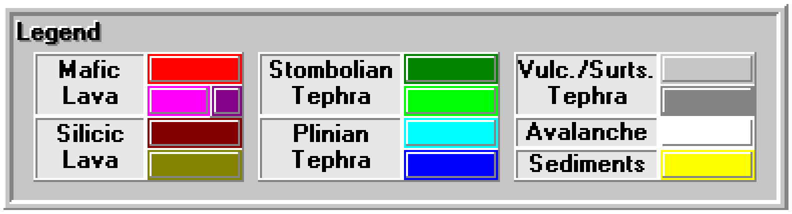
At the bottom of the display is the **Navigation Control** in light blue, showing navigation "direction" arrows that can be pressed by the mouse to start movement. These buttons only are active if the "Start" button is pressed and has becom the "Stop" button. If the Erupt3D Viewer has been opened from Erupt3, it will automatically load the topography created in Erupt3 and the start button will be activated. Also, when opened from Erupt3, Erupt3D veiwer will automatically update its view every 10 seconds as new eruptions happen in Erupt3. The "Reset" button returns the view to it initial home in case you get lost in the hills and valleys. The "Auto" button places the movement arrows in a continuous mode, such that pressing them once starts motion that continues until they are pressed again or the "Stop" button is pressed. The navigation arrow functions can also be operated by the keyboard arrows.

Other controls: During movement around the 3D view, a red circle displays the users location on the small plan view map at the top. While movement is started with the Start button, clicking anywhere on the small map will instantly move your view to that location.

While movement is stopped stopped with the "Stop" button, users may use the "Open" button to load another topography file that was previously saved from Erupt3D Viewer by the "Save" button. Likewise the "Printer" button will open a print-preview window for setting up a printed copy.

Legend

The legend panel can be viewed by choosing "legend" in the view menu. The panel shows the various colors used by erupt to demark stratigraphic layers of different types. While using Erupt, right click on each type to get a quick description of their meaning.



Erupt3 WWW Browser

If you have an internet connection, you can quickly view the ERUPT User Page

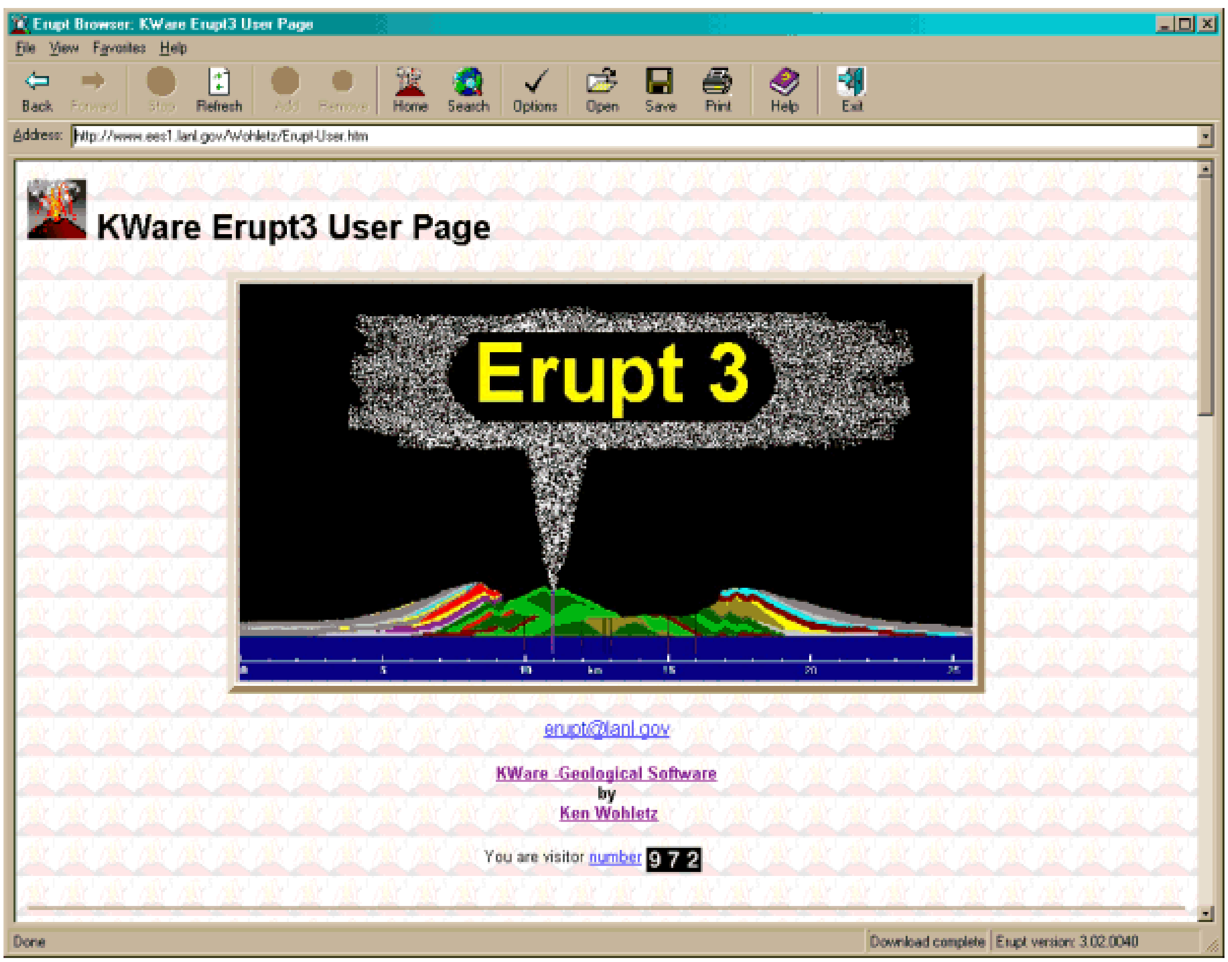
http://www.ees1.lanl.gov/Wohletz/Erupt-User.htm

or browse the internet for volcano items by selecting view/Erupt WWW (or by clicking the browser button on the ToolBar). If your browser application is compatible, the Erupt WWW Browser will be displayed, otherwise, you will be directed to locate your browser application using a file dialogue.

If Erupt uses its own browser the following window will open. This browser window includes menus items for File (open, save, print, exit), View (back, forward, stop, refresh, home, internet, and options), Favorites (add, remove, and the favorites you have added--the Erupt User Page is automatically added to your favorites), and Help (this page). The browser also includes a ToolBar with buttons for these menu items. The ToolBar can be activated/deactivated by clicking the view/options menu item. As with the Erupt ToolBar, the browser ToolBar can be customized by double clicking on blank spaces; your ToolBar configuration will be save for future browser sessions.

The status bar at the bottom of the browser shows your current Erupt software version number, and if this number is less than that shown under "Update" on the Erupt User Page, then you should follow the update link to get the newest version release.

The Erupt browser has default home and search pages defined, but these can be changed by clicking the view/options menu item.

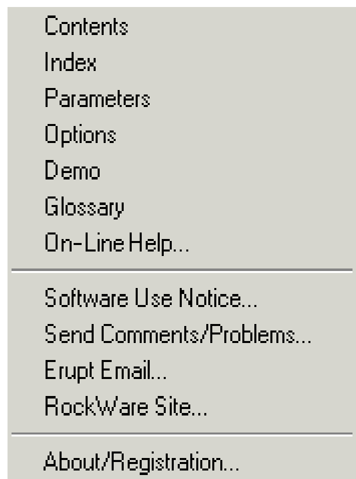


Help with Erupt3

This help file is intended to help users learn how to make eruption simulations and understand the various elements of the program.

If the ToolBar is displayed, help contents can be accessed by the  button.

The help menu displays several items for quick information on this help file (**contents**), an **index** of key words, the **parameters** menu, the **options** menu, a **demo** movie, and the **glossary**. Please go to the contents page to view various topics about ERUPT. Some information about problems with Erupt are addressed on the trouble shooting page.



OnlineHelp starts your internet browser at the Erupt3 Help Page. On this page you can download the most recent version of the help file, since it is not included because of its large size in updates. If Adobe Acrobat Reader is installed on your system, you may also view the most recent help file version on line.

The Software Use Notice displays conditions for using Erupt3.

The About item displays your version of Erupt, copyright information, and a button to view your system information.

The Send Comments/Problems... item opens up a text editor for you to compose a message to the author for help on problems or other comments (including those you would like to have on the Erupt-User www page.

Erupt Email will activate your email program to send an Email directly to Erupt@lanl.gov with a specific subject line preset. Support for shareware versions of ERUPT is limited, but retail support can be obtained through the author.

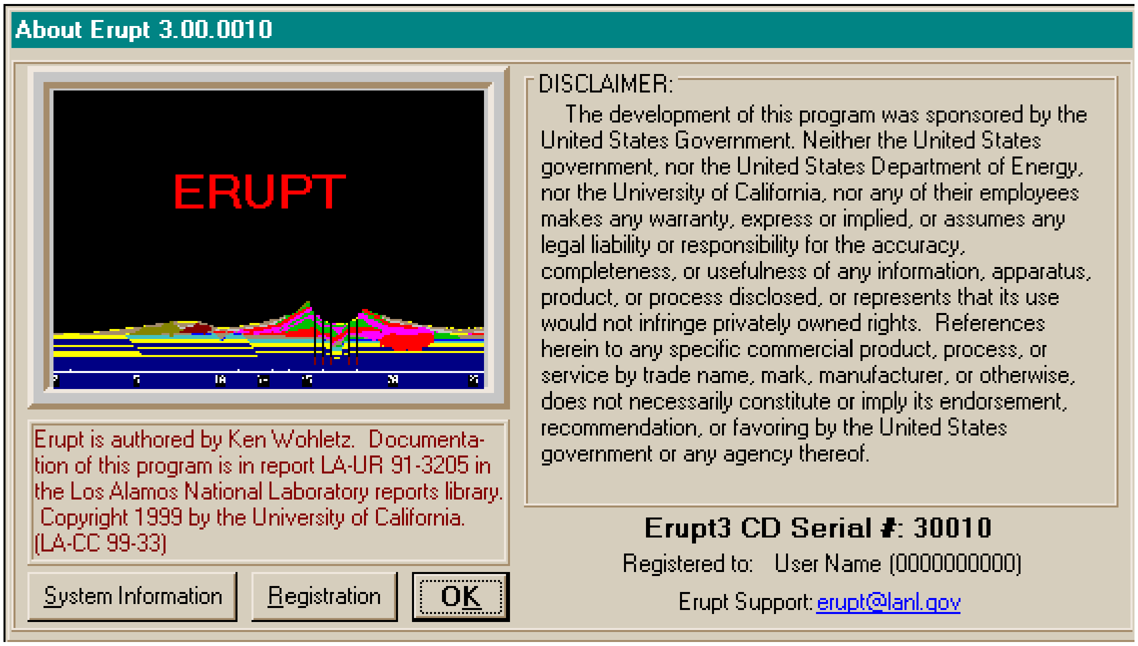
The RockWare Site item is designed to open your browser directly to the their page. **RockWare does not offer support for Erupt3**, but it does offer numerous software products for earth sciences. If you have the Demo version of Erupt3 and would like to purchase it, please go to the RockWare site by clicking this link www.rockware.com.

RockWare Inc ®
Earth Science Software
www.rockware.com
2221 East Street, Golden CO, USA 80401
tel: 303-278-3534 fax: 303-278-4099

About Erupt3

By selecting the "about/registration" item in the Help menu, the following window appears. This window provides buttons to view your computer's **System Information**, to view **Registration** and register your copy of Erupt, and to close the about window (**OK**).

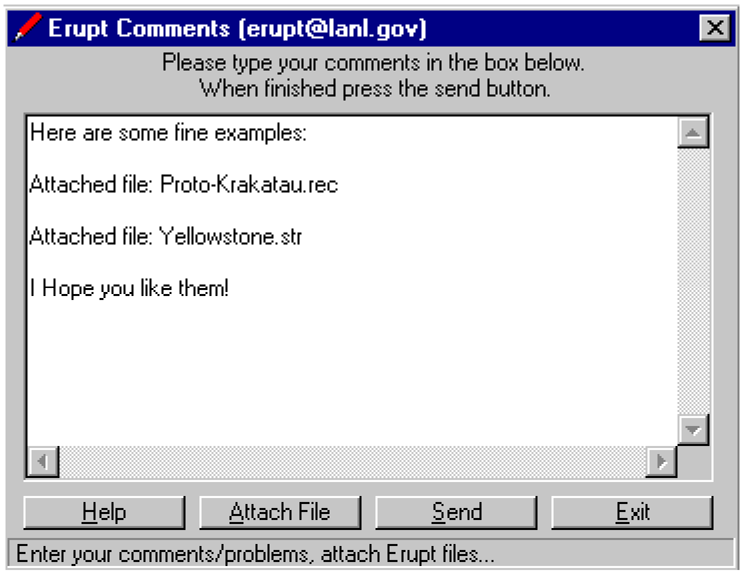
In addition, by right-clicking on the graphic, the user may view a movie of an Erupt simulation.



Send Comments/Problems...

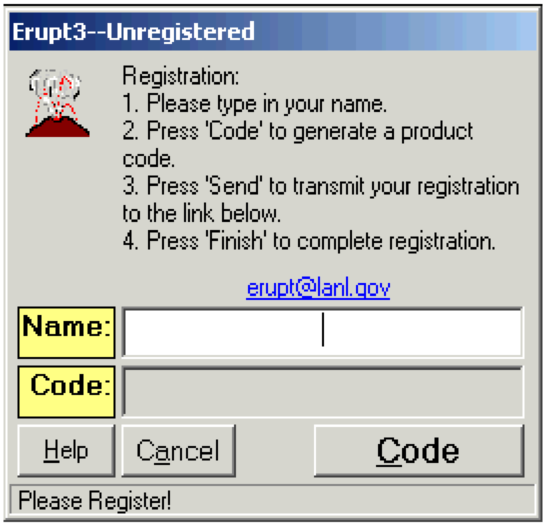
By choosing this item on the Help menu, an editor window opens where you can enter text. Alternatively, you may select the EruptComments program from its icon in the Windows Start menu. Describe any particular problem or make comments about the program. You may also attach Erupt files [stratigraphic (.str), record (.rec), or elevation (.dem), up to one each] to your comments. If you would like to see your comment added to the Erupt-User home page, please indicate so in the text.

When you complete your message, press the send button, and Erupt will attempt to send your message to the Erupt FTP server. If this send task fails, please cut and paste your text into an email message addressed to erupt@lanl.gov



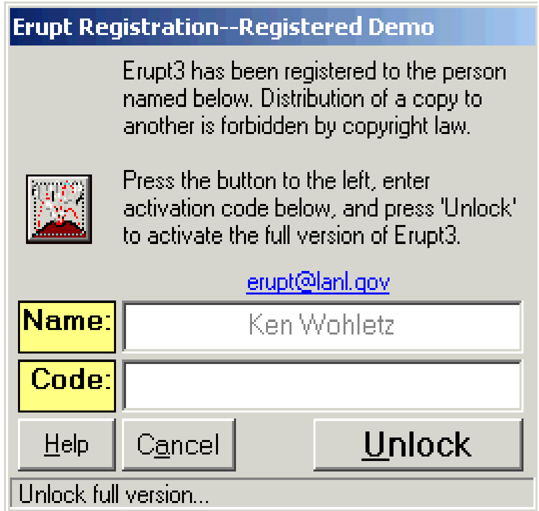
Registration

By registering (free) your ERUPT software, support will be facilitated, and you will receive email notices of updates that you can access and download from the Erupt Users Page. Register by clicking on help-about/registration and the "About Erupt" window will appear. On this window press the register button to register your software. A registration window will appear on which you type your name, then press the "Code" button, which will generate a registration code, and then press the "Send" button to FTP your registration to the author. After completing the FTP registration, press the "Finish" button to return to Erupt. If you press the cancel button before completing by pressing "Finish" your version will not be registered, and you will be asked to register it each time you start Erupt3.



When pressing the "Send" button, for dial-up connections, Erupt3 should automatically start this connection if it is not already started. Under certain circumstances, Erupt will not be able to FTP your registration. In this event, please use your email program and send a message to the erupt@lanl.gov containing your name and code number as it appears on the registration window. Alternatively, you can register by sending a note by post to the author.

For Demo Versions, an option to purchase the full version on-line at www.rockware.com is possible. By making the purchase, an installation CD will be sent to you, and an "activation" code will be emailed to you so you can immediately access the full version from your current installation. Once you have the activation code, open the registration window by choosing "About/Registration..." from the Help menu, and then press the "Registration" button. If you have previously registered then the following registration window will appear.



Press the button with the Erupt icon, type the activation code in the code box and press the "Unlock" button to complete the activation. You will be prompted to re-send your registration information. That's all there is to it!

Software Use Notice

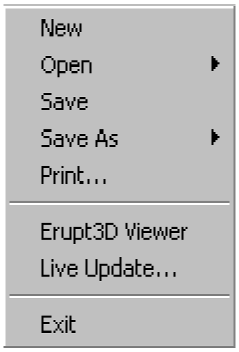
This software and ancillary information (herein called "SOFTWARE") called **Erupt3** is made available under the terms described here. The SOFTWARE has been approved for release with associated LA-CC Number : **LA-CC 99-33**.

Unless otherwise indicated, this SOFTWARE has been authored by an employee or employees of the University of California, operator of the Los Alamos National Laboratory under Contract No. W-7405-ENG-36 with the U.S. Department of Energy. The U.S. Government has rights to use, reproduce, and distribute this SOFTWARE. The public may copy, distribute, prepare derivative works and publicly display this SOFTWARE without charge, provided that this Notice and any statement of authorship are reproduced on all copies. Neither the Government nor the University makes any warranty, express or implied, or assumes any liability or responsibility for the use of this SOFTWARE.

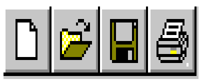
If SOFTWARE is modified to produce derivative works, such modified SOFTWARE should be clearly marked, so as not to confuse it with the version available from LANL.

File Menu Selections

The file menu consists of the following options:



If the user has selected to show the ToolBar* from the options menu, the following file buttons are displayed.



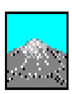
New: Clears results of previous simulations and starts a new volcano growth simulation.

Open: Opens a previously saved stratigraphic file, which serves as basis for continuing simulations, or a digital elevation model (DEM) file, or a eruption record file for playback of a previously recorded eruption sequence.

Save: Saves the currently displayed stratigraphic sequence, or if recording is enabled, the current record of your eruption sequence. This action will default to the current opened file name with the appropriate extension; if none has been specified it will ask for a file name.

Save As: Saves the currently displayed stratigraphic sequence, or if maps are enabled, a digital elevation model of your current volcano, or if you have recorded your eruption sequence you can save the eruption record for future playback. This option is convenient for changing the current file name.

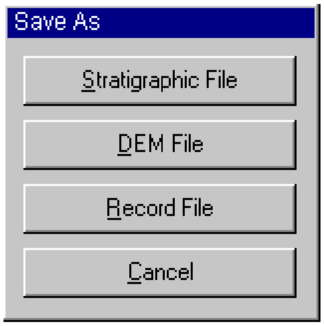
Print: Print consists of options for (1) printer setup, such as resolution, dithering, color options, and orientation; (2) printing the plot only scaled to your chosen paper size; and (3) printing the Erupt Window to show menus and legend or parameters window--this option will not scale to your paper size, so you may have to change the Erupt Window size to fit on you paper.

Erupt3D Viewer: Starts the  Erupt3D Viewer application for viewing previously saved topographic images and new topography as it is being created in Erupt.

Update..: Starts the  EruptUpdate program, which makes an FTP connection to check if your version can be updated. If a new version is available and you choose to continue with the update, Erupt will be unloaded and new files will be automatically downloaded and installed by just following the directions provided by EruptUpdate. By checking the "Auto Update Notification" item in the Options menu under "Advanced," Erupt3 will automatically notify you if an update is available each time you start Erupt3, provided that an internet connection is active.

Exit: Ends the Erupt Program.

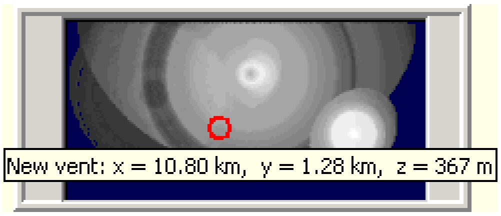
*ToolBar: If the ToolBar is used, selecting file open and save displays the following option panel.



Erupt 3D Vent Position

When the option "Enable Map 3D Position" is checked a small panel will be displayed when new eruption parameters are selected. This panel will show a rendering of the current topographic map with a red circle that designates the current vent location. Clicking anywhere on the map will move the vent location to a new horizontal location. This method is more graphically intuitive for placing a vent location than if it is manually set in the eruption parameters panel and in the Advanced Parameters Panel.

The panel will close upon pressing the "OK" button in the eruption parameters panel, but it will reappear after completion of an eruption. To manually close the panel, left click on the map border.



Command Line Options:

Command line options are set by adding "/l" , "/a", "/f" or any combinations (e.g "/al") in the program manager file or shortcut properties text box.

The "/l" loads the default stratigraphic profile, which is useful to start with a substrate that can be changed by eruptions or tectonic events.

The "/a" automatically starts erupt in the auto eruption.. By specifying "/al" loads the default stratigraphic profile before starting the auto-eruption mode.

The "/f" option start ERUPT in the fast simulation mode but disabled sound in supported.

Status Bars

Status bars are positioned at the top and bottom of the Erupt window.

The upper bar shows the currently selected eruption type (manually selected from the parameters menu or automatically chosen by the auto erupt mode) and the current eruption status, including the eruption cycle and burst number and pre/post eruption activities (such as dike emplacement, erosion/faulting events, and caldera collapse).

The lower bar shows current configuration settings and options, including the date and time, the name of the currently opened Erupt file, the simulation speed chosen, the gravity setting, the record status, the map status, and the current erupt mode chosen.

Techniques

Several techniques are required to simulate realistic volcanoes and volcanic fields while using Erupt, and a few suggestions are given here.

Keep you Erupt files up-to-date: Be sure to check for new versions using the EruptUpdate program or by choosing 'Update' from the File menu.

Build up a basement stratigraphy: A layered stratigraphy existing below a simulated volcanic field is convenient for showing tectonic, erosion, crater excavation, and caldera collapse. The default stratigraphic file "Erupt3.str" provides this basement stratigraphy as alternating layers of blue and yellow color (no specific rock type specified). The default stratigraphy can be loaded any time a new file is loaded by checking the option in the option menu.

Composite cones: A composite cone is built by cyclic activity generally starting with fluid lava flows later alternating with scoria, pumice and ash, and dome growth. To simulate this type of volcano, mix your eruption parameters in a cyclic fashion for a given vent location. Late in the development of the cone, try a Mazama caldera eruption by selecting the Plinian or Vulcanian parameters, or try a sector collapse eruption, such as occurred at Mount St. Helens.

Specify number of particles: By specifying many particles (50 maximum) for explosive eruptions, the animation becomes more realistic and tephra accumulate faster but eruptive bursts require more computational effort and thus proceed more slowly.

Save files: By saving files, the user can recall a previous eruption simulation stratigraphy for continued study. In addition, if the recorder option for recording an eruption history is checked while making a simulation, the whole record can be saved and replayed at a future time.

Reproduce documented stratigraphy: Find a geological paper describing the history and stratigraphy of a volcanic field. Try to reproduce the field by studying the vent(s) age, location, and eruption type as well as the stratigraphic thickness of each unit. This is a good method to better understand a particular volcano or volcanic field, especially if it is one you are currently mapping yourself. This exercise can be made even more challenging if the user enables mapping such that the 3-D vent location can be controlled. An example, using advanced techniques is shown with 3-D simulation for an hypothesized 6th century eruption of Krakatau volcano.

Describe an auto-mode volcanic sequence: Set Erupt for auto eruption and let it run for a while. Turn on the recorder for future playback. Practice describing the history of the hypothetical volcano/volcanic field produced by Erupt.

Study erosion effects: Erosion variously affects rocks depending upon their in-situ consolidation and elevation. Tephra is more easily eroded than lavas, but high-standing rocks are eroded more than those in low areas.

Consider volcanic hazards: Many volcanoes follow cyclic eruption behavior with explosive phases occurring after periods of dormancy and effusive stages following explosive ones.

Change scales: study small volcanoes with the small volcano option and larger volcanic fields with the large-scale option. It is easy to move up in scale, but when the user goes from larger to smaller, a portion of the volcano/volcanic field may be truncated.

Share your interesting results: Use the EruptComments program (or open in from the Help menu) to send your saved stratigraphic (or better, your record files) to the Erupt FTP server (or by email to erupt@lanl.gov; a convenient link is provided on the Erupt User home page) with a description of your simulation. These results will be posted on the Erupt home page for others to download and enjoy.

View a movie of Erupt in Action! PLAY

Volcano Physics

Magma Chambers and Their Contents: *Magma* is essentially molten rock existing in fractures and filling caverns below the earth's surface. For rocks to be molten, existing as a pasty fluid, they must be at a temperature of greater than 900º C (1670º F). This temperature increases with increasing depth (pressure) below the earth's surface, so that deep in the earth's mantle, even though rocks are hotter, they still exist in a semi-solid state. It is only when this viscous and plastic rock is pushed close to the surface that it starts to behave like a fluid and flow.

Most rocks are dominantly composed of silica (SiO_2), which is the main component of ordinary glass. So like ordinary glass they become gooey when heated above their melting point. Rocks also have a lot of alumina (Al_2O_3), lime (CaO), soda (Na_2O), potash (K_2O), iron (FeO + Fe_2O_3), and magnesia (MgO). Depending upon the abundance of these major components, magmas tend to have different physical properties, such as density and viscosity. For example, magmas composed of molten mantle rocks will have silica abundance in the range of about 40 to 50 % by weight while those magmas derived from crustal rocks will have higher silica in the range of 60 to 77 %. The other major components also vary in a systematic way from deep mantel to crustal magmas. This composition variation in general results in mantle magmas being hotter, denser, and more fluid than crustal magmas.

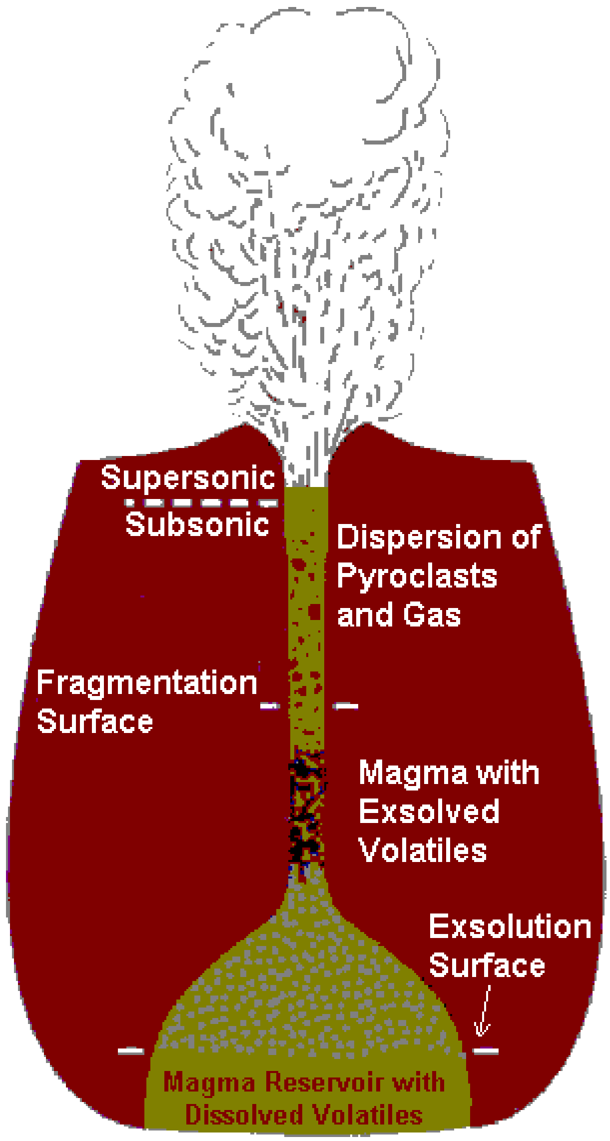
Where erupted onto the earth's surface, magma is termed *lava*. Mantle-derived lava is generally called *basalt*, and it is a dark-gray to black in solidified color and often relatively fluid. Crustal-derived lava is termed *rhyolite*, and it is a medium to light gray in solidified color but is generally very thick and pastey. Magmas do change in composition (*differentiate*) while they stew in magma chambers before eruption, and basaltic magmas may mix with rhyolitic ones. Differentiation and magma mixing result in intermediate magma compositions termed *andesite* and *dacite* of lower and higher silica content, respectively. To be sure, there are dozens of terms applied to the many variations in magma chemistry, depending upon the various combinations of chemical constituents.

When lava cools, some of the liquid forms tiny mineral crystals (from < 0.1 mm to > 10.0 mm) called *phenocrysts* while the rest of the magma quenches into a glass. The most common phenocrysts are quartz, feldspar, olivine, and pyroxene. The amount and size of phenocrysts in lava depends on how fast the lava cooled. If lava is quickly quenched, few if any phenocrysts have time to develop and the resulting rock is mostly glass, such as *obsidian*.

Effusive Lava Eruption: In general hot magma rises to the surface as a buoyant mass, because it is less dense than the host rocks in which it resides. If it is not less dense, it may just cool beneath the earths surface forming an igneous rock body called a pluton, a dike, or a sill. Still dense magmas may have enough gas pressure to be pushed upwards despite their density, but upon emergence at the surface, their is not enough gas pressure to make an explosive eruption. The manner by which magma is extruded on the surface as lava depends mostly upon its viscosity, or resistance to flow. Fluid basaltic magmas flow readily forming long rivers of lava that travel downslope. Thick, pastey rhyolite lavas do not flow easily, and they tend to mound up to form steep-sided domes. These effusive lavas are typified by Hawaiian (basaltic) and Peléean (rhyolitic) eruptions. In some cases Peléean eruptions can become explosive, if vapor pressure builds up within the congealed lava dome.

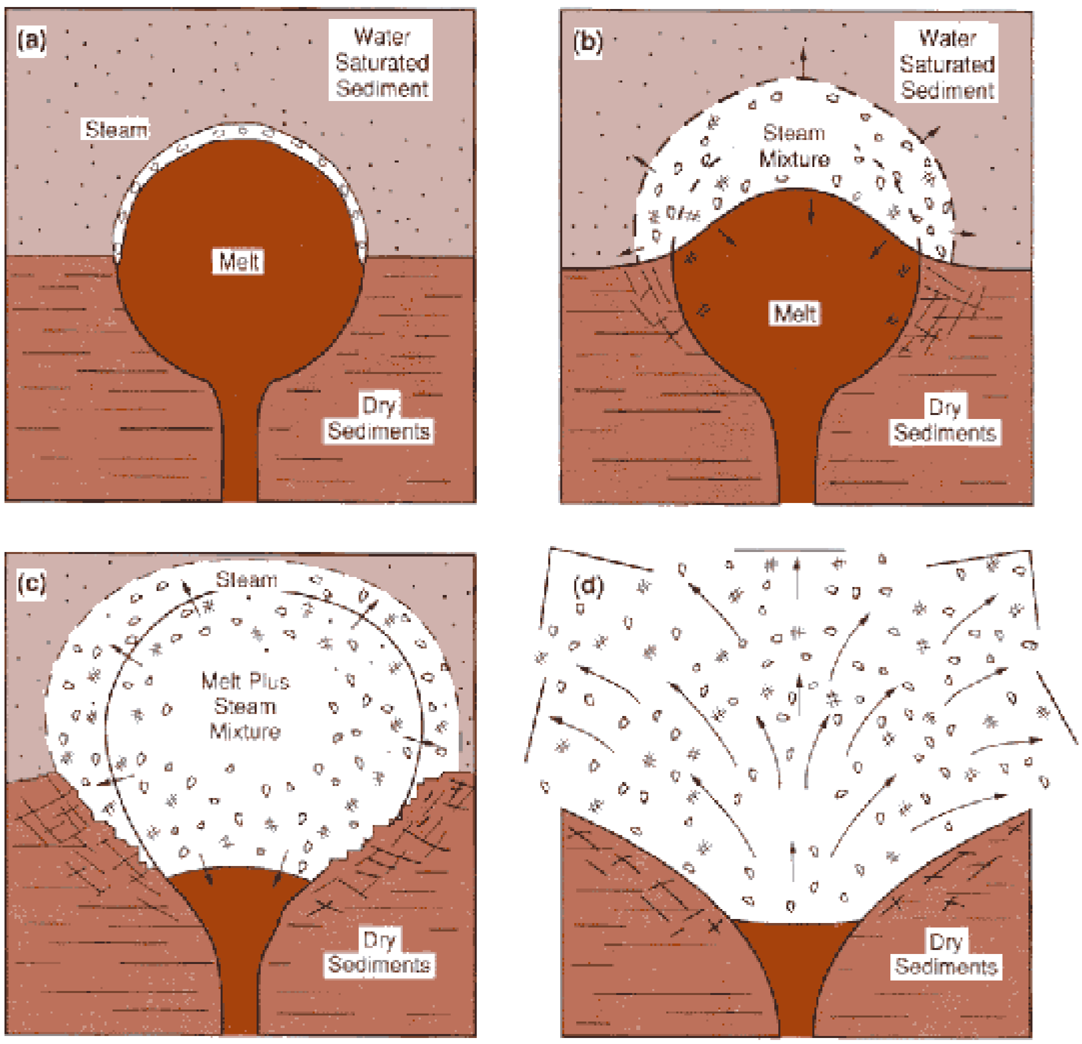
Explosive Eruption: Magmas generally have volatile (gaseous) components, chemicals that form vapor when pressure is released. Common gaseous components of magmas are water, carbon dioxide, hydrogen, sulfur dioxide, chlorine, and fluorine. Of these components water is the most abundant, generally making up from 90 to 95 % by weight of the gas escaping from magmas. For *magmatic* eruptions these volatile substances are initially dissolved in magma, much like carbonation is in carbonated beverages. As the magma stews and differentiates, these light volatile substances rise and concentrate near the top of the magma chamber. When pressure is release from the magma as it vents to the surface, these volatile substances come our of solution to form vapors. During this process the volume occupied by water, for example, rapidly increases over 1000 times. This rapid increase in volume drives explosive eruptions. On the other hand the gas driving an eruption may be mostly water that is vaporized by the magma as it encounters underground or surface water bodies. This type of explosive eruption is termed *hydrovolcanic*.

For **magmatic** eruptions, the illustration below shows a magma chamber charged with volatiles. With opening of the vent to atmospheric pressure, an expansion wave moves down the volcanic conduit into the magma chamber. Above this low pressure wave (exsolution surface) in the chamber, volatiles come out of solution and form bubbles of gas. The growth of these bubbles pushes the bubbly magma up the conduit. As this bubbly mixture rises, the bubbles continue to grow with ever decreasing pressure on them until they merge, making the mixture a gas with suspended fragments of magma. This gaseous dispersion forms at a level called the fragmentation surface; the fragments are called *pyroclasts*, composed of pieces of *ash* and *pumice*. The dispersion then accelerates towards the surface moving ever faster until it reaches a point where its speed becomes supersonic. Now moving faster than it can send pressure waves ahead of it, it drives a shock wave out of the vent with a rapidly expanding gaseous plume. This kind of eruption mechanism produces *Plinian* and *Strombolian* eruptions.



Magmatic eruption physics

During **hydrovolcanic** eruptions, Magma (melt) rises into water-saturated host rocks (such as porous sandstones). The heat from the magma boils the water residing in the pores forming a high-pressure steam cap. This steam cap is very unstable and rapidly expands and collapses, breaking up the sediments and the magma into fine pieces and promoting mixing of fragmented magma with the wet sediments. Eventually, the melt plus steam mixture attains large enough volumes and pressures that the sedimentary rocks fail, breaking apart, and allowing the mixture to explode through the surface forming a large crater. The magma fragments formed by this eruption are typically very tiny (< 0.1 mm) and are called *hydroclasts*. This kind of eruption mechanism is involved in most *Vulcanian* and *Surtseyan* eruptions

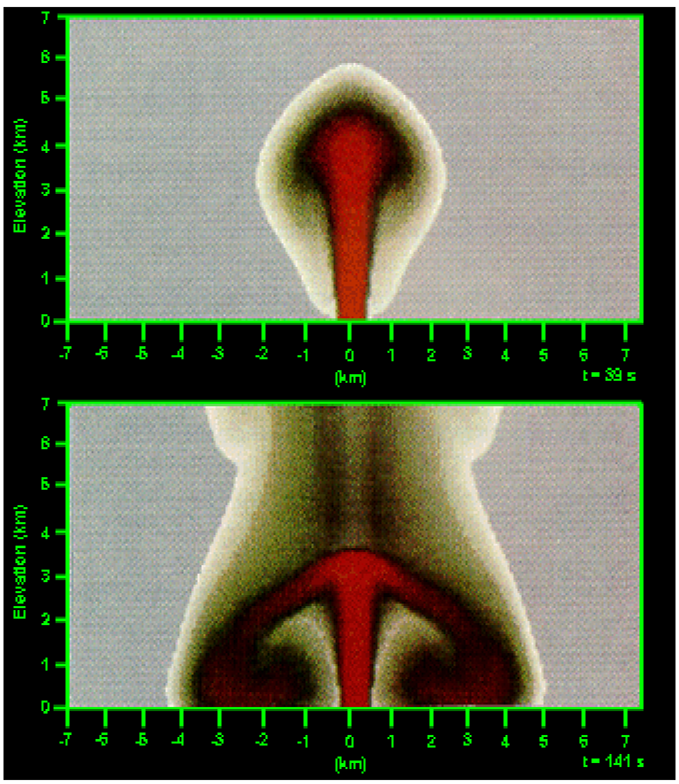


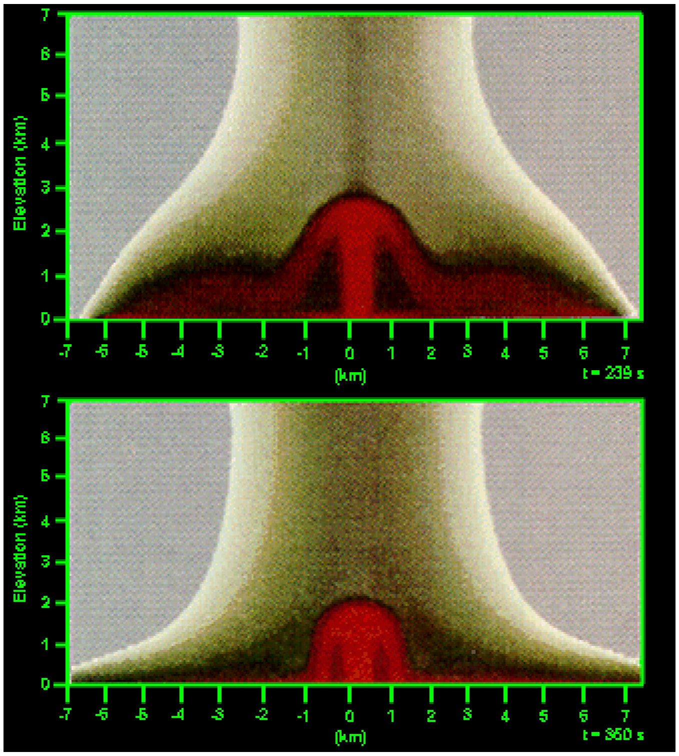
Hydrovolcanic eruption physics

Numerical Simulations

The numerical simulations done at Los Alamos National Laboratory in Los Alamos, New Mexico involved complex computer codes that required several hours of the most advanced Cray supercomputers. The simulation solved a set of 8 equations that express the physical processes of mass, momentum, and energy conservation, also known as the Navier-Stokes equations. These equations are a set of multidimensional, non-linear, differential equations that are coupled by 8 additional equations that express the constitutive relationships of the magma and gases simulated as well as the interactions between the magma and gases. These 16 equations were solved over and over again for discrete points in space at intervals representing about one to several milliseconds. Simulations were carried out over several hundred seconds of modeled time. The results were equivalent to thousands of pages of numbers, but these numbers were analyzed and converted in graphs and animations that show the development in time and space of explosive eruption columns by their temperature, density, speed, and pressure. The following plots show the growth Plinian eruption column at 39, 141, 239, and 360 seconds, represented by the density and temperature of the column (red: hot and dense). Just before 140 seconds, the column becomes unstable and collapses on itself to start a laterally moving pyroclastic flow.

While these and similar numerical simulation supported the validity of the hypothethized physics involved and allowed for some very important predictions, only a few institutes around the world have the capability of reproducing them. In addition, the complexity of making these simulations limited them to modeling just a few types of eruptions. For these reasons, ERUPT was developed.




Elevation (km)
(km)
t = 239 s
Elevation (km)
(km)
t = 360 s

ERUPT: A GRAPHICAL SIMULATION OF VOLCANIC ERUPTIONS FOR THE PERSONAL COMPUTER

(LA-UR-91-3205)

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ABSTRACT

ERUPT is a user interactive computer program designed to simulate a wide range of volcanic activity and display it two-dimensionally. Written to take advantage of Microsoft WindowsTM3.X, 95, and NT operating systems with multimedia, a DOS version is available requiring only EGA/VGA screen capability. The program involves numerical solution of basic physical laws of motion to reproduce a variety of eruption phenomena including: (1) Vulcanian/Plinian pyroclastic surge and flow; (2) Strombolian scoria fall; (3) mafic lava flows; (4) silicic lava dome emplacement; (5) Plinian pumice fall; and (6) sector collapse. The graphical display shows the temporal and spatial evolution of particle paths for lava and pyroclasts, their deposition, and the construction of a volcanic edifice in two dimensions. In addition, structural modifications to the simulated volcanic stratigraphy can be added by caldera collapse and normal faulting options, as well as dormant periods of erosion and redeposition. The program can be either run in an auto mode for semi-random eruption evolution or an interactive mode for operator controlled specification of eruption evolution. The basic physics involved includes those of simplified Newtonian/Bingham flow of lava with an arbitrary yield strength for silicic lavas, modified ballistic equations including the effects of turbulence and buoyancy for Strombolian, Plinian, and flow/surge eruptions, and an energy line approximation for conservation of kinetic energy, during runout of pyroclastic flows and surges. With its simple user interface, this program is aimed at students of volcanology as a teaching aid. Research applications include reproduction of the structure and stratigraphy of a known volcanic field to understand its physical volcanologic history and demonstration of various eruptive events at known volcanoes to illustrate volcanic hazards for nontechnical audiences.

INTRODUCTION

Personal computers have become an integral part of geological data representation, modeling, and interpretation. Within the realm of volcanology, many research projects have benefited from computer applications; for example, those of petrological data interpretation and plotting (Carr, 1987), tephra stratigraphic correlation and interpretation (Wohletz and Sheridan, 1979), solution to analytical expressions of Plinian eruption column physics (Woods, 1988), topographic interaction of pyroclastic flows and surges (Malin and Sheridan, 1982; Wadge and Isaacs, 1988), and rheological models of lava flows and domes (Iverson, 1989; Ishihara et al., 1989; Baloga, 1987). Such programs are proving very timely for workers in the ever more quantitative aspect of volcanological research.

Within the realm of physical volcanology, computer simulations can be of tremendous help in evaluating potential volcanic hazards as well as deducing those observed through deposit mapping. Graphical simulations also can greatly simplify the illustration of complex eruption phenomena when communication of volcanological concepts to lay people is required. In general there is a need for teaching aids in illustrating and introducing some basic concepts of eruptive mechanisms as well as the evolution of volcanic edifices of several classical types, including shield volcanoes, silicic domes, calderas, composite volcanoes, tuff cones and rings, and scoria cones, to name but a few. In recognition of such a need, Dehn

(1987) developed a parametric model for cinder cone growth, which has in turn inspired the development of the initial algorithm for ERUPT.

Wohletz and Valentine (1990) and Dobran et al. (1993) described results of super computer models of explosive eruptions. Although these models give very precise solutions to the governing equations of the eruptions and allow development of detailed video representations, the complexity of the codes and requirements of very sophisticated computer hardware makes their general application by students and researchers difficult. The intent of the computer program ERUPT, described here, is to offer a streamlined and simplified eruption simulation program that allows students and researchers to easily experiment with various eruptive mechanisms and their lava/tephra emplacement mechanisms to reconstruct typical volcanic landforms.

The computational method of ERUPT is briefly described below, followed by some examples that illustrate its capabilities. Finally we discuss some of the code's possible applications as well as its current limitations. With continued use, we plan for many potential modifications and improvements.

PROGRAM DESCRIPTION

ERUPT graphically portrays four types of explosive eruptive activity (pyroclastic surge and flow, ballistic scoria ejection, pumice fall, and sector collapse) and two types of effusive activity (lava flow and lava dome). Each type has a set of associated parameters such as vent location, wind speed and direction, and relative strength of the eruption. The screen displays a dike intrusion and then the program calls subroutines that simulate the selected eruption. Eruptive episodes portray repeated bursts of lava or pyroclasts by tracing the movement of representative parcels on the screen. Simulated volcanic sounds accompany each eruptive type. At the end of each eruptive burst the various products are displayed as a stratigraphic horizon with a distinct color. Because arrays are written to record the thicknesses and type of emplaced products, the screen can be refreshed at any time and the user can save the results for future simulations.

ERUPT is fully interactive allowing menu oriented selection of eruption parameters and their editing at any point in the simulation. In addition, a fully automatic mode selects and modifies eruption parameters to show evolution of hypothetical volcanoes and volcanic fields with time. The automatic mode is semi-random while following predetermined evolutionary trends such as those of a composite cone, silicic volcanic field development, and shield volcanoes.

In interactive mode ERUPT prompts the user to choose one of the five different eruption types and its associated parameters for each episode. The duration of the eruptive episode is controlled by the user who can terminate it at any time. This allows the user the option to introduce a tectonic or erosional event, select a new eruptive type, product, or moving into automatic mode.

The automatic mode makes selections of eruptive types and parameters as well as the duration of the eruptive episode. The selections are semi-random, based upon conditional probability of one type of eruption following another.

ERUPT is a modular code written in VisualBASICTM, involving 30 subroutines that handle the setup of the simulation, screen representation, and eruptive modes. A simplified flow chart shows the general design of the code (Fig. 1). Compiled versions of the code can easily be run on personal computers with numeric coprocessors; the simulation speed is automatically set to accommodate the higher clock speeds of newer processors. Scaling of eruption simulations is based upon a screen dimensions of 1280x640 pixels, where each pixel by default represents 20 m (vertical and horizontal scales are equal), such that the screen width is equivalent to 24.6 km. The velocities of eruption products are scaled to the screen, with time stepping iterated at artificially high speeds in order shorten simulation times. Because of the range in spatial dimensions of eruptions, (for example between weak Strombolian bursts and caldera forming ignimbrite eruptions) the graphical scale is arbitrary to some degree. While the DOS-version memory limits the number of eruptive phases (changes) that can be simulated (40); up to 100 separate stratigraphic units and vent locations can be displayed in the Windows version. When memory limits are reached, only the static eruption mode is available, which displays parcel trajectories but does not add them to the stratigraphic array.

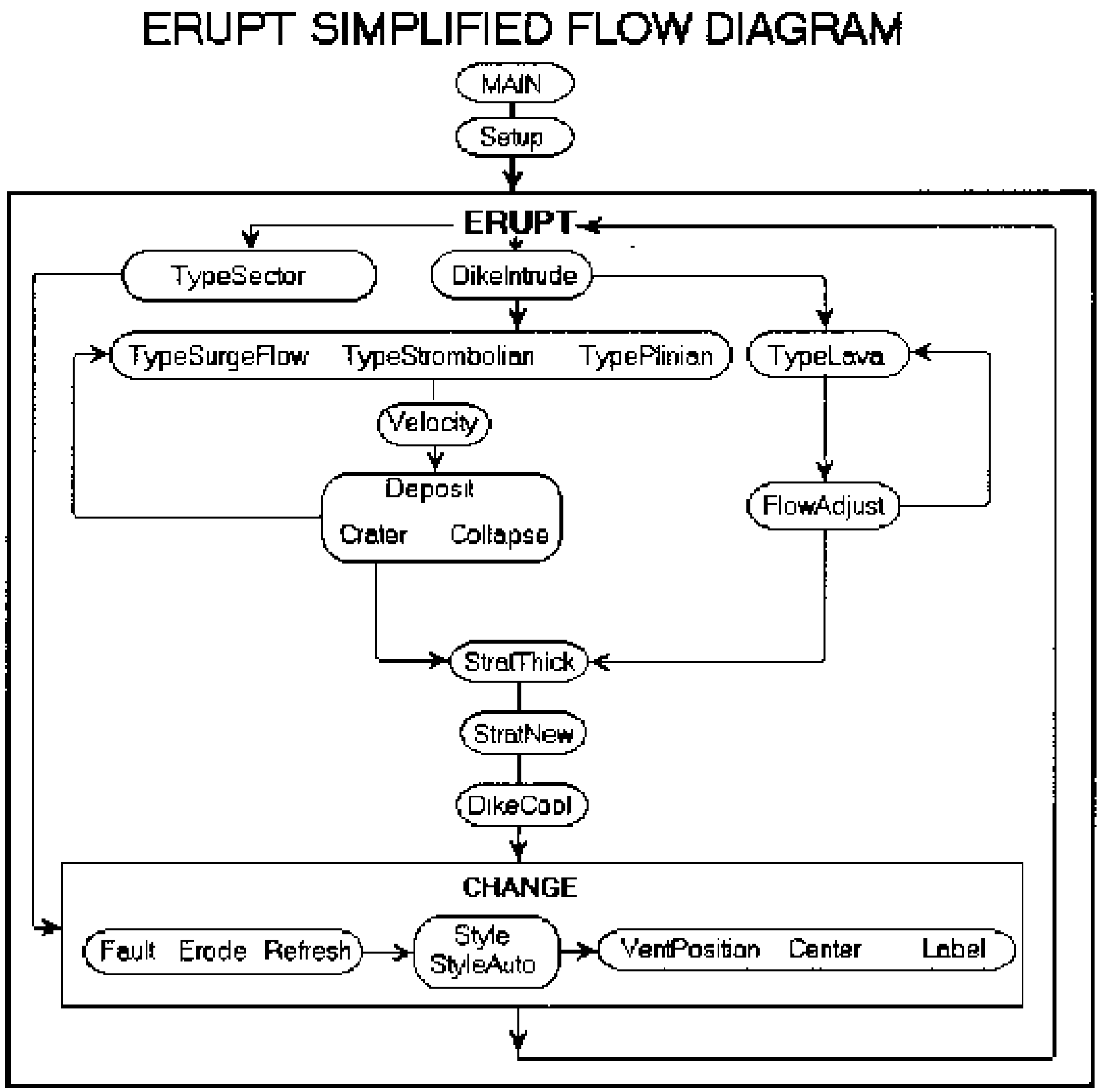


Fig. 1. Simplified flow chart of ERUPT.BAS (version 1.0) with only the primary subroutines shown. Subroutine ERUPT loops recursively until up to 40 eruptive stratigraphic units have been recorded. After dike intrusion, one of four eruptive-type subroutines is called; pyroclastic types require trajectory velocity calculation, deposit emplacement, cratering, and if chosen, caldera collapse; lava types call a flow adjust subroutine instead of deposit, crater, and collapse ones. The eruptive type subroutine loops through as many bursts as desired or predetermined by auto-mode selection. After completion of eruptive-type bursts, stratigraphic thicknesses are determined and then added to the graphic screen before dike cooling occurs. The ERUPT subroutine is completed by a set of CHANGE subroutines that give the user options for faulting, eroding, screen refreshing, choice of a new eruptive type and it vent position. With establishment of a new eruptive center and screen labels, CHANGE loops back to the beginning of ERUPT.

The modular form employed in ERUPT has developed with the concept of making code modifications simpler. Such modifications are desirable where ERUPT is taken from the teaching applications to research problems, requiring special circumstances of modeling. The physics used by ERUPT are greatly simplified, but retain enough detail to make graphical illustration of eruptions that look real as well as display observed spatial parameters.

General Formulation of Eruption Physics

Pyroclastic Eruptions. A kinematic algorithm is used to display the trajectories of pyroclasts for explosive eruptions. Graphic parcels, representing groups of pyroclasts, are assigned ballistic trajectories with initial conditions selected as a random function of the relative eruptive strength. The number of representative parcels is user designated with a default set proportionally to the eruptive strength chosen. A modified parametric form of the ballistic equation is then used to map out the temporal evolution of each parcel's flight path:

$x(i) = [vx + vf(i)]t + vwt$, (1)

$z(i) = [vz + vf(i)]t + (g/2)\ t2$, (2)

where x(i) and z(i) denote incremental lateral and vertical position, vx and vz are the vertical and horizontal velocity components, g is the gravitational acceleration (which can be set to simulate various planetary conditions), and t is time. The magnitude of the lateral and vertical velocity components is scaled by user-specified strength with trajectory angles randomly computed to be between about 45° and vertical. These simple ballistic trajectories may be altered by wind [velocity denoted by vw in Eq.(1)]. For the case of Plinian eruption columns (pumice falls) and pyroclastic surges/flows (collapsing eruption columns and directed blasts) a turbulent component is simulated by addition of incremental random fluctuating velocities [vf(i)] in Eqs. (1) and (2).

The runout distance of pyroclastic flows and surges follow the energy line formulation of Malin and Sheridan (1982):

$a(i) = g(\sin b - m\cos b)$, (3)

where a(i) denotes incremental acceleration determined by gravity (g), the local slope of the substrate (b), and the Heim coefficient (m), which is the tangent of the energy line slope. For these eruptions, a simple complementary function of the Heim constant determines the relative eruptive strength, based upon the observations of Sheridan (1979) who shows that large volume pyroclastic eruptions are generally associated with smaller Heim coefficients.

Effusive Eruptions. Simulation of lava flows and lava dome extrusions are based on Newtonian movement of lava parcels over existing topography. Differences in viscosity are simulated by the graphic parcel thickness and flow velocity. These variables produce characteristic long thin lava flows and short stubby domes in a fashion similar to that described by Ishihara et al. (1990). The direction of flow front movement is controlled by surface slope. The flow surface shape of lava is nearly flat whereas the dome surface is convex upward.

Stratigraphic and Structural Representation

Each parcel tracked in explosive eruptive types is assigned a depositional volume as a function the eruption strength parameters. The location where the parcel strikes the substrate is the location where a given volume of tephra will be added to the stratigraphic array. For effusive eruptions, the lava volume of each eruptive episode is a function of the parcel thickness and length of the flow. Because of angle of repose limitations, tephra deposits are smoothed after deposition: scoria accumulations are avalanched to reach steepness of no more than about 35°. The deposit gradient for pyroclastic flows and surges is a function of eruption strength parameter [Heim coefficient; Eq. (3)]; low values of the coefficient result in very low bedding surface slopes whereas high values can retain steep bedding surfaces, which reflects tephra cohesion.

Normal faulting is a morphological control of volcanic fields and edifices. The faulting is either caused by regional tectonic movement or by local readjustment of a volcanic edifice. An example is slumping of the flank of a shield or composite volcano or development of a rift structure. Normal faulting is achieved by user or automatic specification of the location and magnitude of a fault (the amount of dip is randomly selected). The head wall side is then shifted down by the specified amount of magnitude by subtracting y-location pixels from each stratigraphic unit represented.

Along with deposition and avalanching of tephra, explosive eruptions excavate a crater whose width and depth is again a function of the strength or Heim coefficient (Malin and Sheridan, 1982)). Pyroclastic flow/surge eruptions are modeled to produce wider craters than do scoria eruptions. Caldera collapse is modeled as a pair of normal faults centered around the last active pyroclastic flow/surge or pumice fall vent. This option is available for pyroclastic flow/surge eruptions whose Heim coefficient is <0.40 or for pumice fall eruptions of strength >0.5. These option assignments are base upon the general observation that caldera collapse is generally associated with larger-scale eruptions of relatively greater surge/flow mobility or pumice dispersal. Two types of caldera collapse can be selected: one where the crater excavation is not enhanced and another where a large portion of the volcano is removed (called the Crater Lake type). The amount of collapse is proportional to the number of eruptive episodes (duration) and relative strength.

Erosion Model

Erosion is based upon a numerical form of a diffusion equation (Harbaugh and Bonham-Carter, 1970; Pollack, 1969). The temporal change in elevation by erosion or sedimentation is equal to the spatial derivative of an erodibility constant times the topographic gradient:

$$dz/dt = (d/dx)\,(K\,dz/dx) = K\,d^2z/dx^2 + (dK/dx)(dz/dx)\ , \quad (4)$$

where x and z represent lateral and vertical position, respectively. The erodibility (K) is a product of the stratigraphic erosional resistance coefficient and elevation, both of which in turn are functions of x. A spatial averaging technique is applied to transform the diffusion equation into a numerical form and through iterations across the preexisting topography, higher points are eroded and deposition occurs at lower points with erosional preference applied to topography that is high, convex upwards, and/or has a relatively higher erodibility constant. The erosion continues to process each topographic location until the operator halts the function or it reaches the predetermined number of erosional iterations specified by automatic mode operation.

EXAMPLES

The following examples illustrate the main eruptive types while showing the sequential development of a volcanic field stratigraphy. ERUPT designates pumice eruptions as Plinian, scoria eruptions are synonymous with Strombolian, and pyroclastic flow/surge eruptions are referred to as Ignimbrite/surge (MacDonald, 1972).

Plinian Eruption

Our pumice eruption simulates a Plinian event (Walker, 1981) that sustains a vertical column of pumice up to 15 km above the vent. At some height, depending upon the relative eruption strength, the column reaches neutral buoyancy and its upward migration is halted while lateral dispersion begins forming what is called an umbrella cloud. In Fig. 2, a second pumice eruptive phase from a vent located at km 11 models a Plinian column of strength 0.80 which reaches a height of about 10 km. Note the lateral shearing of the umbrella cloud by the wind of 25 m/s directed toward the right. The fallout deposit of pumice shown by the circles thins exponentially away from the vent.

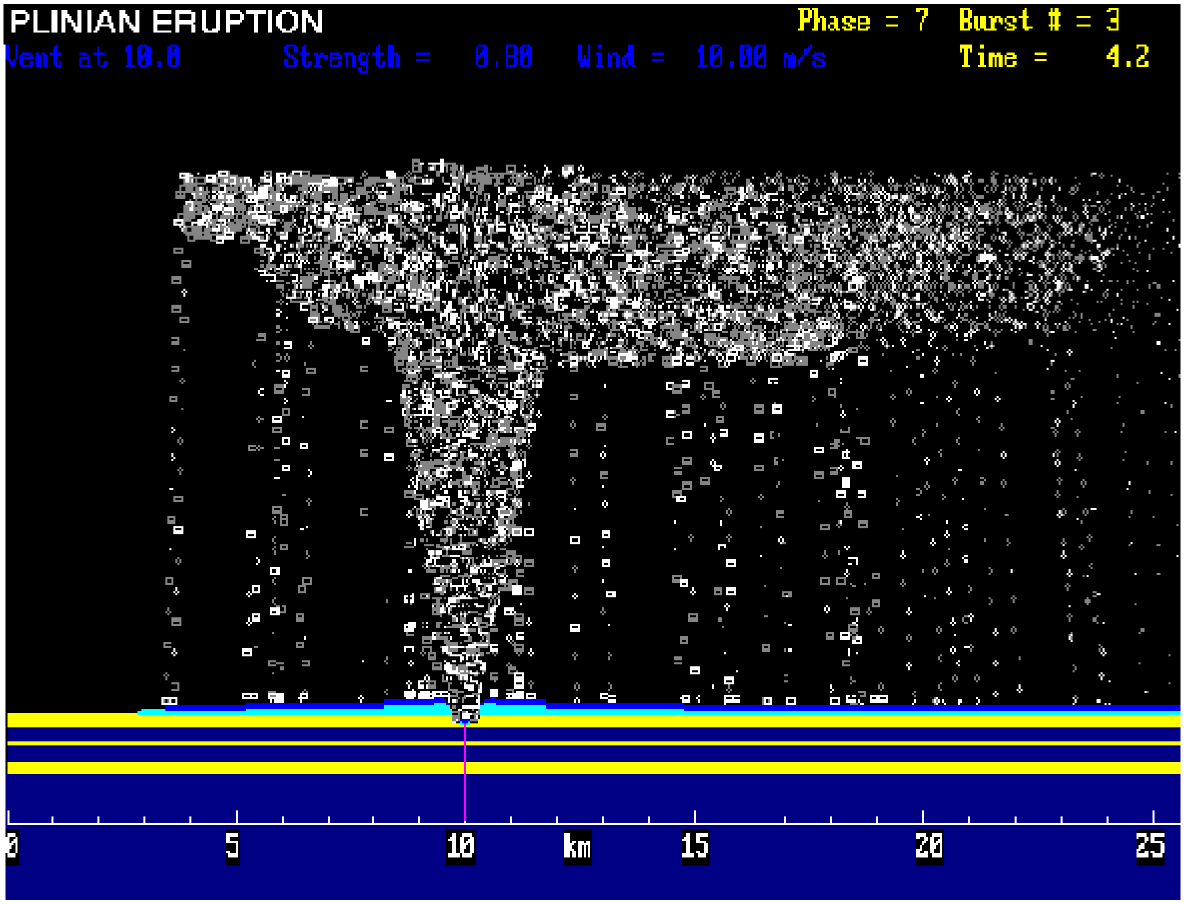


Fig. 2.

DOS screen representation of a Plinian pumice eruption at kilometer 11.0. Note the column rising about 8 km before spreading laterally with a simulated wind of 25 km/hr blowing to the right. Fallout of pumice occurs on previously deposited layers represented by blue colors.

This eruptive behavior is simulated by vertically directed ballistic trajectories that have superimposed turbulent fluctuations representing the support of the parcels in a buoyantly rising medium. The maximum simulated heights of parcel trajectories is arbitrarily limited by assuming a neutral buoyancy height at which point the parcel's lateral velocity component is displayed. At times when the theoretical ballistic trajectories of the parcels fall below the neutral buoyancy height, the parcels are shown to fall out of the umbrella region along a ballistic path to the ground where they are deposited.

Strombolian Eruption

This simple form of pyroclastic eruption type is based upon the parametric ballistic equation already described; technical description of the eruption physics can be found in McGetchin et al. (1974). Each particle is tracked through time until it intersects a topographic surface or moves out of the field of view. The parcels are traced by small colored circles on the screen; the color of each parcel changes with time to simulate chilling from red-hot lava to dark colored scoria clasts. The strength of the scoria eruption determines the magnitude of the randomly assigned velocity vectors for each parcel. With solution of the parametric ballistic equation, a variable wind factor and gravitational constant modify the appearance of the erupted fountain. Where parcels y-position intersect the topographic surface, deposition occurs subject to later downslope avalanching.

Eruptive phase 9 (Fig. 3) shows a Strombolian eruption and scoria cone at kilometer 21.0. This cone is superimposed on the flanks of the previous scoria cone centered at kilometer 18.0, which rests upon the previously described Plinian deposits. The strength of the eruption is 1.00, which produces a ballistic fountain about 2.5 km high. The eruption has produced a scoria cone with a base diameter of about 4 km and a height of 1.5 km with a large central crater.

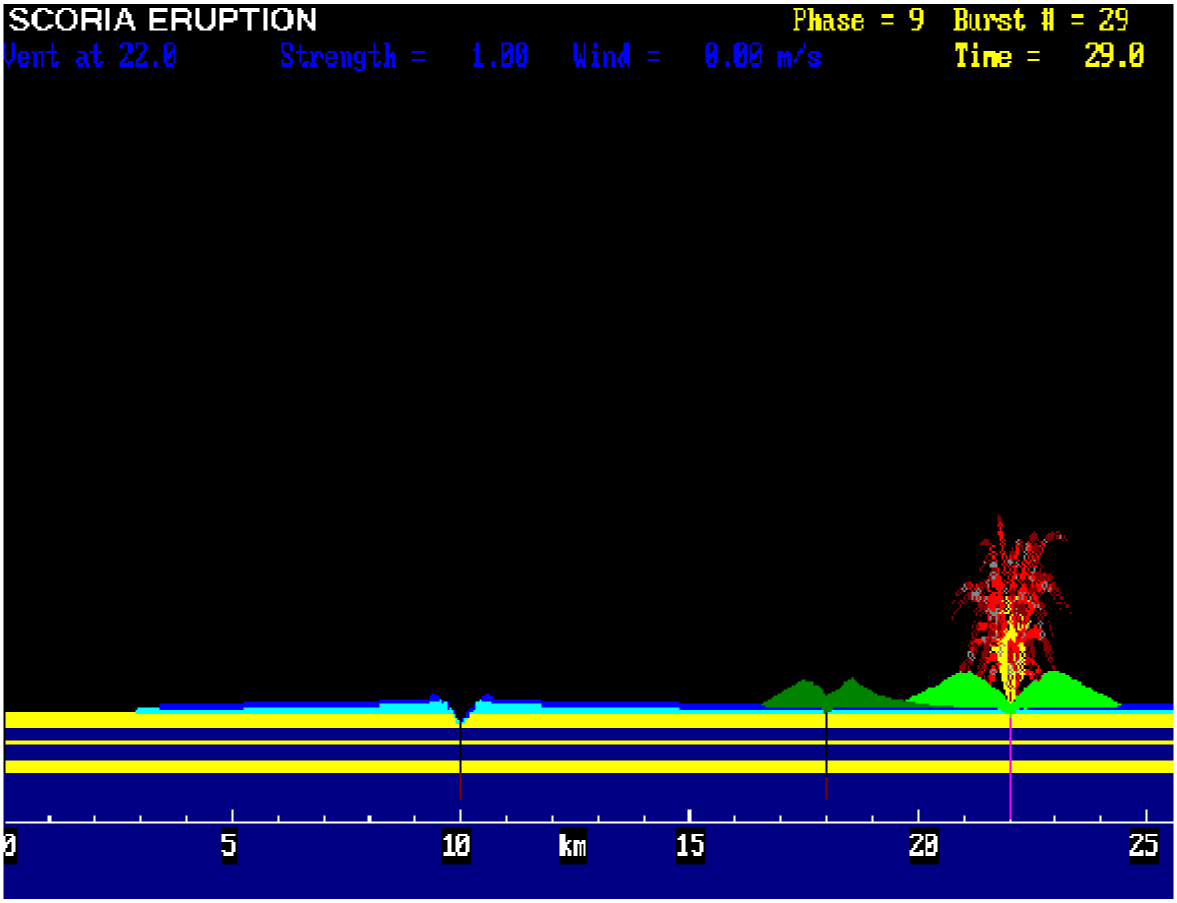


Fig. 3.

A Strombolian eruption at kilometer 21.0 produces a ballistic fountain in phase-4 eruptive bursts. The scoria layers (green) show phase 9 deposits onlapping the older phase 8 scoria cone.

Pyroclastic Flow/Surge

Pyroclastic flows or Ignimbrites(Sparks and Wilson, 1976) and pyroclastic surges (Wohletz and Sheridan, 1979) are laterally moving density currents of tephra and gases formed during several different eruption types, most notably including Plinian, Peléean, and Vulcanian (MacDonald, 1972). This type of simulation is accomplished by superposition of turbulence on the parcel's ballistic trajectory and conversion of the parcel's potential energy to laterally directed kinetic energy of translation. Ballistic trajectories for each representative particle are randomly generated. Turbulence is introduced by adding a random fluctuation to the trajectories. The ultimate runout of the surge/flow is governed by the energy line concept described by Eq. (3). The initial potential energy of each particle is a function of the height of its ballistic trajectory. This height is converted into a runout distance as a function of the Heim coefficient, which predicts the energy line, a hypothetical line that connects the highest point of origin of the flow/surge with the most distal point of its runout. For example, pyroclastic flows from composite cones display typically high Heim coefficients (>0.4), but caldera-related pyroclastic flows can be highly mobile with runout distances more than 20 times greater than the vertical distance they traverse (Heim coefficient < 0.05). In solving the lateral movement of representative parcels, the parcel's acceleration or deceleration is iteratively calculated by the vertical distance between the parcel and the topography directly below it. If this distance is less than that of the previous iterative position, then deceleration occurs; if the topography is dipping outward from the vent with a slope greater than that of the energy line, then the parcel will accelerate (see Malin and Sheridan, 1982).

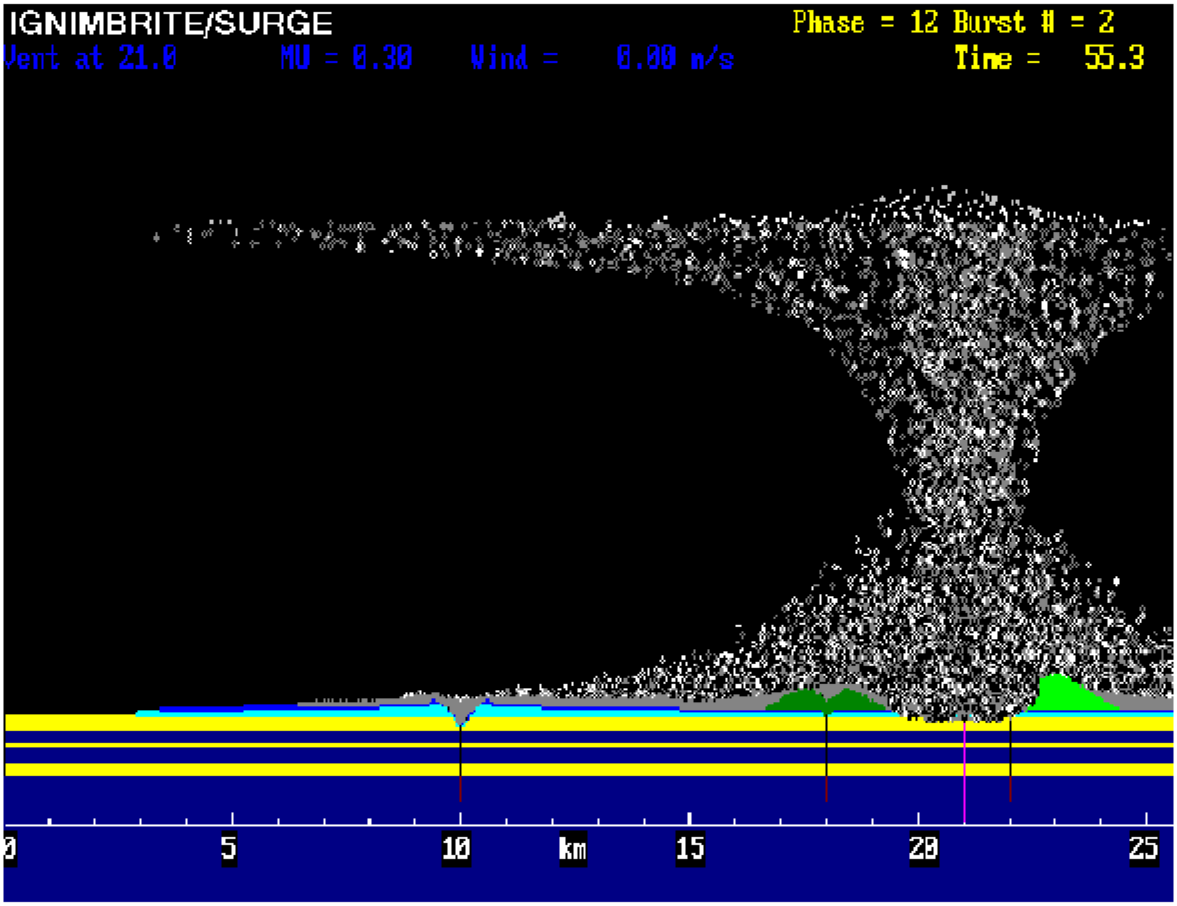


Fig. 4

shows a ignimbrite/surge eruption on the flanks of the previous scoria cone at kilometer 20.0. The Heim coefficient is 0.3 and with no wind the total runout is about 15 km. Note that the deposit, shown in gray, is thicker in topographically lower areas but gradually thins away from the source. The eruption has excavated a bowl shaped crater.

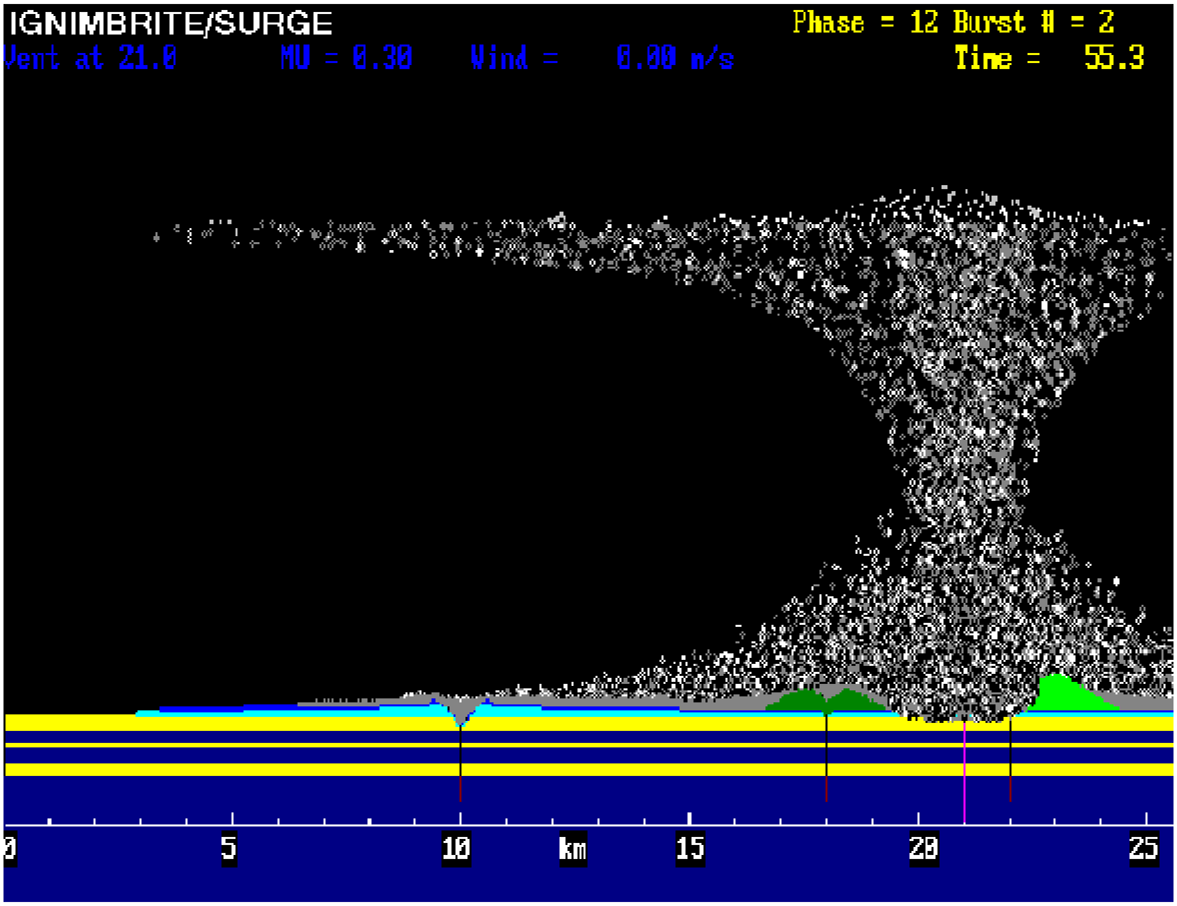


Fig. 4.

Pyroclastic flow/surge eruption (Ignimbrite/surge) of phase 12 occurs in an evolving crater at kilometer 20.0. The eruptive column rises about 10 km above the vent and collapses to cause runout of density currents over 10 km outward from the vent. The deposits of this eruptive phase are shown in gray. Note the crater excavation in the phase 9 scoria cone.

Lava Flows and Domes

Effusive activity is simulated by Newtonian fluids that move down slope under gravity (Hulme, 1974; Fink, 1983). The volume of each eruptive episode is randomly determined, with large volume flows having a greater likelihood of producing a longer flow. Lateral movement of the flow is dictated by the difference in height of the flow top and adjacent topographic elements. A Bingham-like yield stress (Hulme, 1974) is simulated for viscous dome lavas by an increased thickness of flow parcels and higher viscosity is represented by a slower translation rate of those parcels. Downslope movement will proceed as long as lava parcels continue to be extruded. Where a flow meets a topographic obstacle, the ability of the flow to overtop that obstacle is determined by the relative height of the obstacle to the lava's upstream height. Because lavas become more viscous with cooling, the effective hydraulic head of the lava is not necessarily the difference in height between its vent and flow front. For long flows the effective head is determined by the difference in height of the flow front and some effective source location upstream. With these methods of rheological simulation, lava flows tend to pond in topographically low areas while dome lavas will pile up into mounds.

A lava vent shown in Figure 5 at kilometer 17.0 has produced a shield volcano on the flanks of a previous lava flow that ponded in the crater of the pyroclastic surge/flow eruption discussed earlier (Fig. 4). The shield has a collapse crater. In this program collapse craters form when large volumes of lava have been erupted. In contrast, Fig. 6 shows the extrusion of a viscous lava dome at kilometer 11.0 on the flanks of a previously erupted dome at kilometer 10.0.

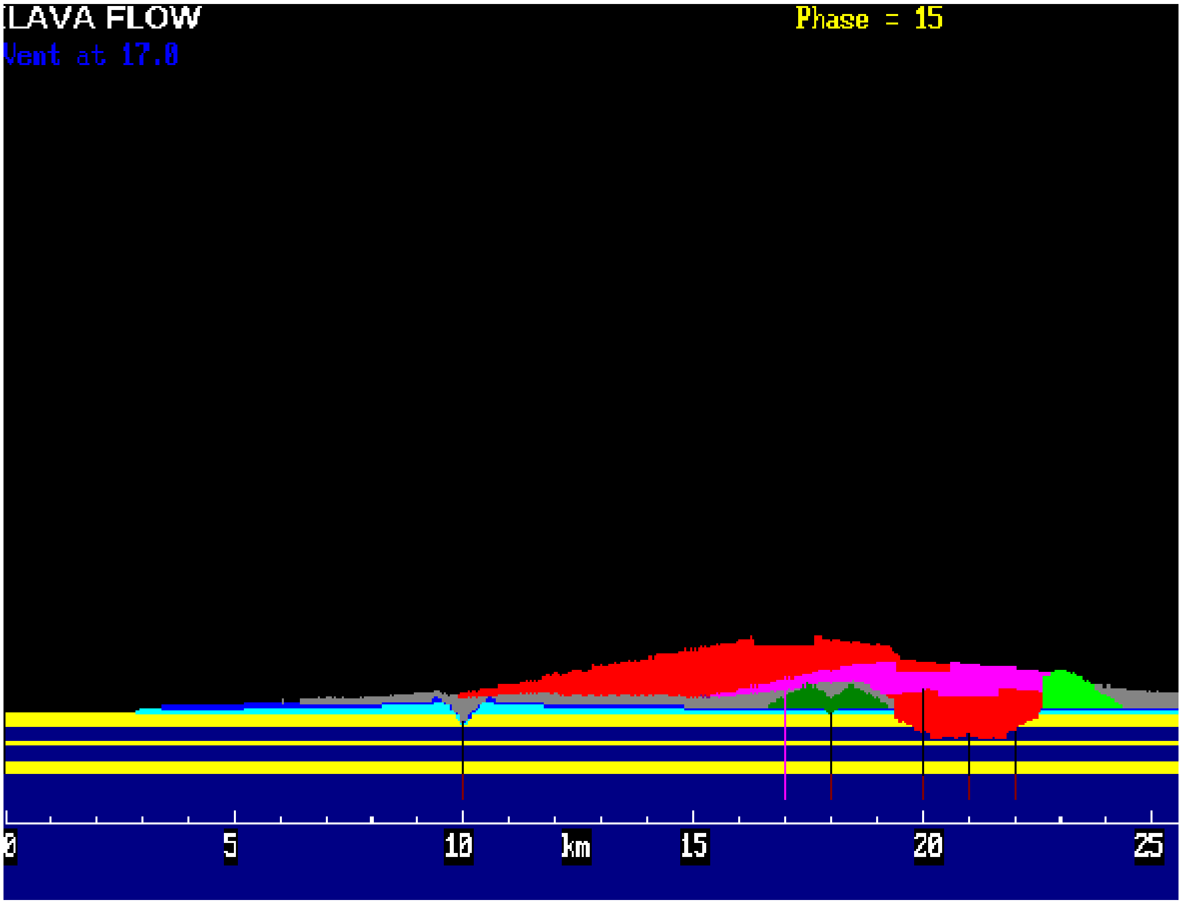


Fig. 5.

Phase 13 through 15 eruptions are basalt-like lava flows (red and purple) that have built a lava shield centered near kilometer 17.0. Because these lava eruptions continued sufficiently long, crater collapse is shown above the vent areas.

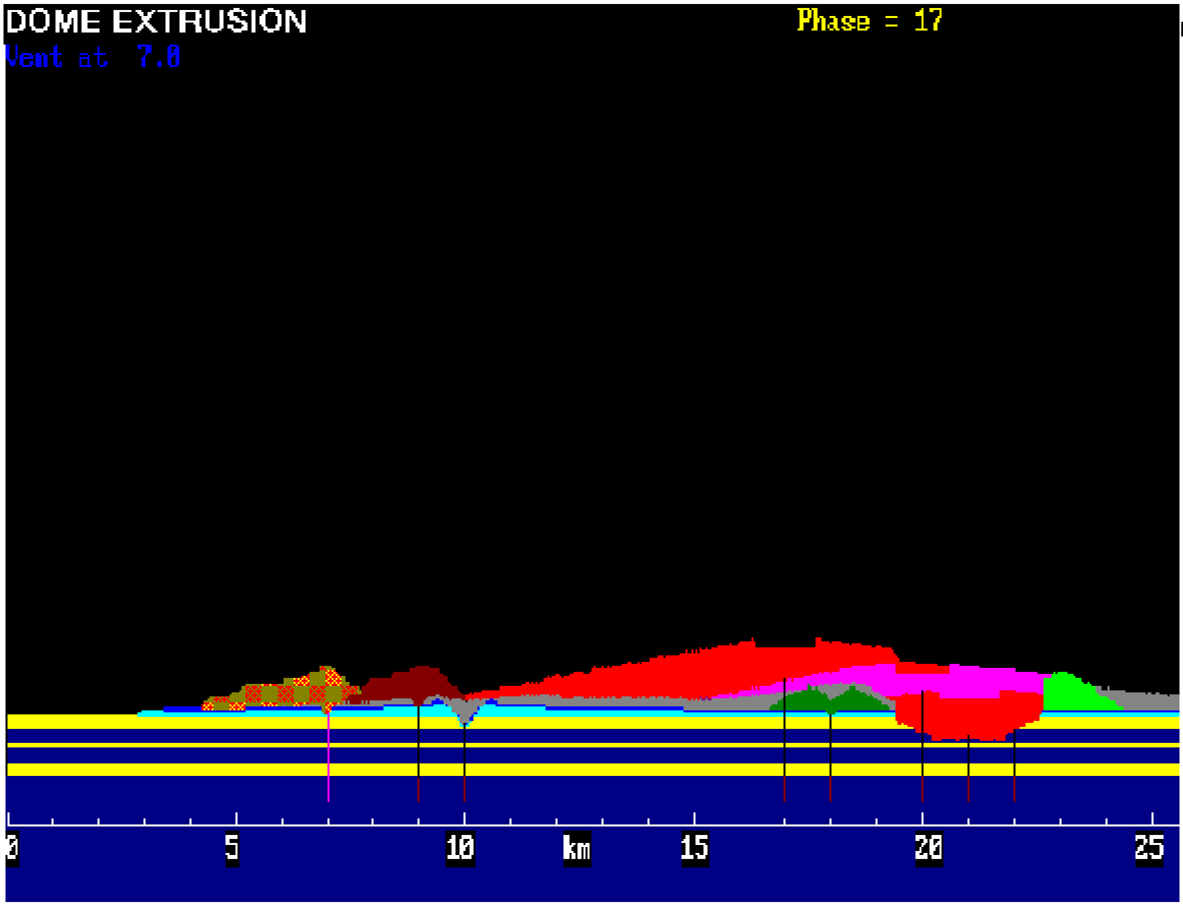


Fig. 6.

Lava domes at kilometers 10.0 and 11.0 have resulted from phase 16 and 17 eruptions. The dome lavas are shown as brown colors. Note the relatively steep-sloped flanks of these domes compared to those of the lava flows of previous phases.

Erosion, Faulting, and Caldera Collapse

Figure 7 (phase 18) shows the dormant eruptive phase 10 where their has been a normal faulting event followed by a period of erosion upon the earlier developed volcanic stratigraphy of Fig. 6. The fault is located near kilometer 15.0 and is of moderate magnitude with the right-hand side down-dropped several hundred meters. As described earlier, the erosion model takes into account differential erosion based upon elevation and erosional resistance. Figure 7 illustrates the effects of erosion by the truncation of the lava shield; its top is smoothed preferentially with respect to the younger lava domes. Horizontal stripes portray the resulting sedimentary deposits that cover the flanks and bury the fault scarp.

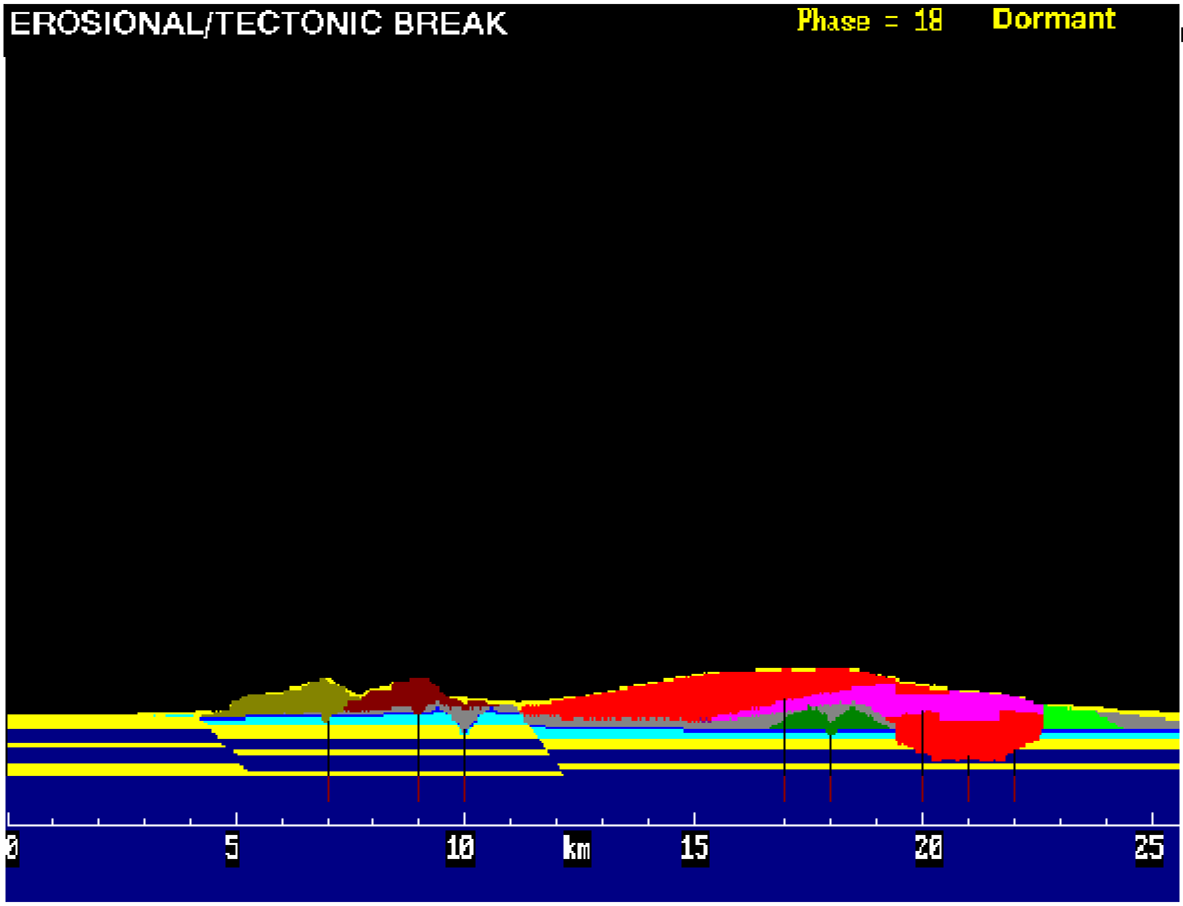
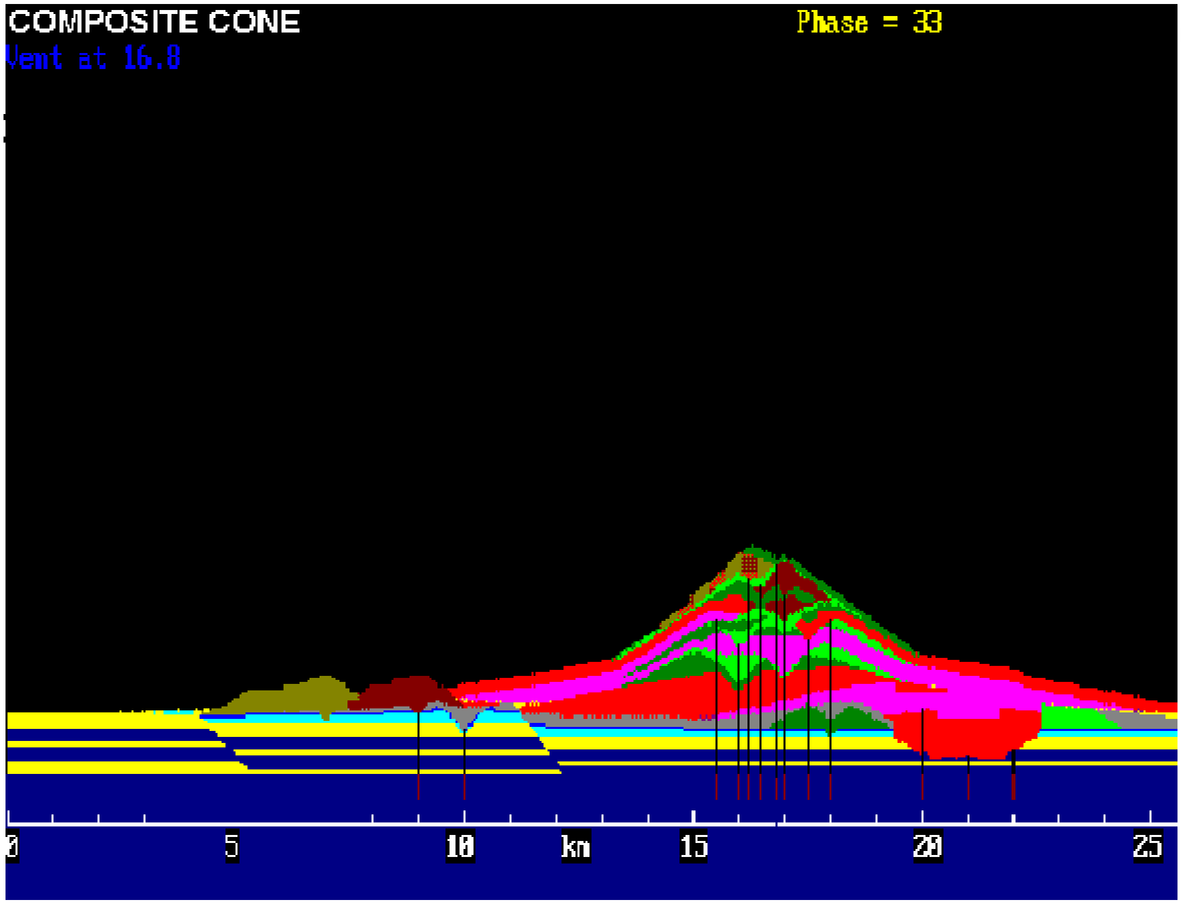


Fig. 7.

Phase 18 is a dormant period marked by formation of a normal fault near kilometer 15.0 (note downdrop of pyroclastic layers to the right of the fault). In addition, this dormant phase shows an erosional break marked by relatively greater truncation of the previous lava shield that is more erodible dome lavas. The sedimentary deposit resulting from the erosion break is shown as horizontal lines.

In order to illustrate caldera collapse (Williams, 1941) a large composite volcano was generated on top of the previously eroded volcanic stratigraphy. The composite cone eruptive phases (Fig. 8) comprise a repeated sequence of lava flows and scoria eruption with dome extrusion in the crater formed by the last scoria eruption, and finally a erosional phase. Caldera collapse is simulated by a large summit pyroclastic flow/surge eruption (Heim coefficient = 0.2), and the resulting truncated cone with a summit caldera depression is shown in Fig. 9. A blanket of tephra has been deposited over all the previous stratigraphic units and the caldera (Crater Lake type) is some 4 km in diameter and about 2 km deep. Down-drop of the central portion of the volcano is displayed between a set of inwardly dipping faults about 4 km apart. Finally, a small scoria cone has been erupted in the caldera (Fig. 9).

Fig. 8



Eruptive phases 19 through 33 have produced a large composite cone consisting of alternating layers of lava and scoria with a small summit dome.

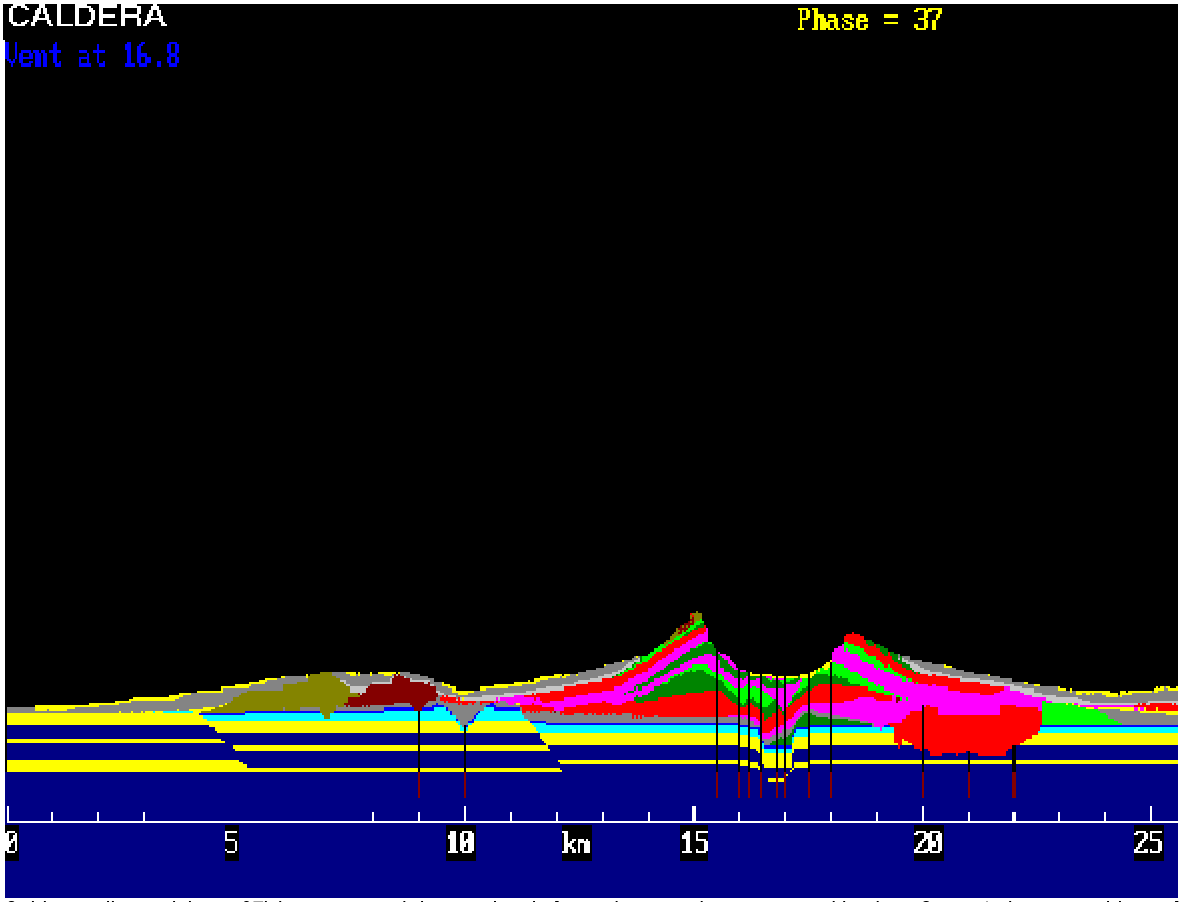


Fig. 9.

Caldera collapse (phase 37) has truncated the previously formed composite cone, resulting in a Crater-Lake-type caldera of about 4 km diameter and 2 km deep. The blanketing pyroclastic deposit from the caldera eruption (gray) is not shown within the caldera; however, if the Crater-Lake-type option were not chosen, the pyroclastic deposit would be thickest inside the caldera, but the topographic expression of the caldera would not be so pronounced. Note the inwardly dipping caldera faults along the caldera walls that cause downward displacement of precaldera units under the caldera.

Volcanic Sector Collapse

Since the 1980 eruptions of Mount St. Helens, sector collapse has been increasingly recognized as an important type of eruptive activity especially displayed during the evolution of composite cones and domes (Siebert, 1984). Sector collapse results from gravitational instability of rocks comprising the slopes of the volcanic edifice as a result of a variety of geological processes including erosive oversteepening of the slopes, progressive fumarolic alteration and weakening of the slopes, and intrusive displacement of the edifice. These processes and others cause a portion (sector) of the volcano to break loose and avalanche downslope producing debris flows that extent several or more km away from the base of the volcano. ERUPT simulates this activity by a combination of low-angle faulting and erosion that produce both a dust cloud and debris avalanche deposit as a portion of the volcanic edifice is removed (Fig. 10). The user specifies the position of the collapse head scarp thus determining its magnitude. We note that some unusual results can occur by poor choice of the location of a sector collapse and advise caution in its application.

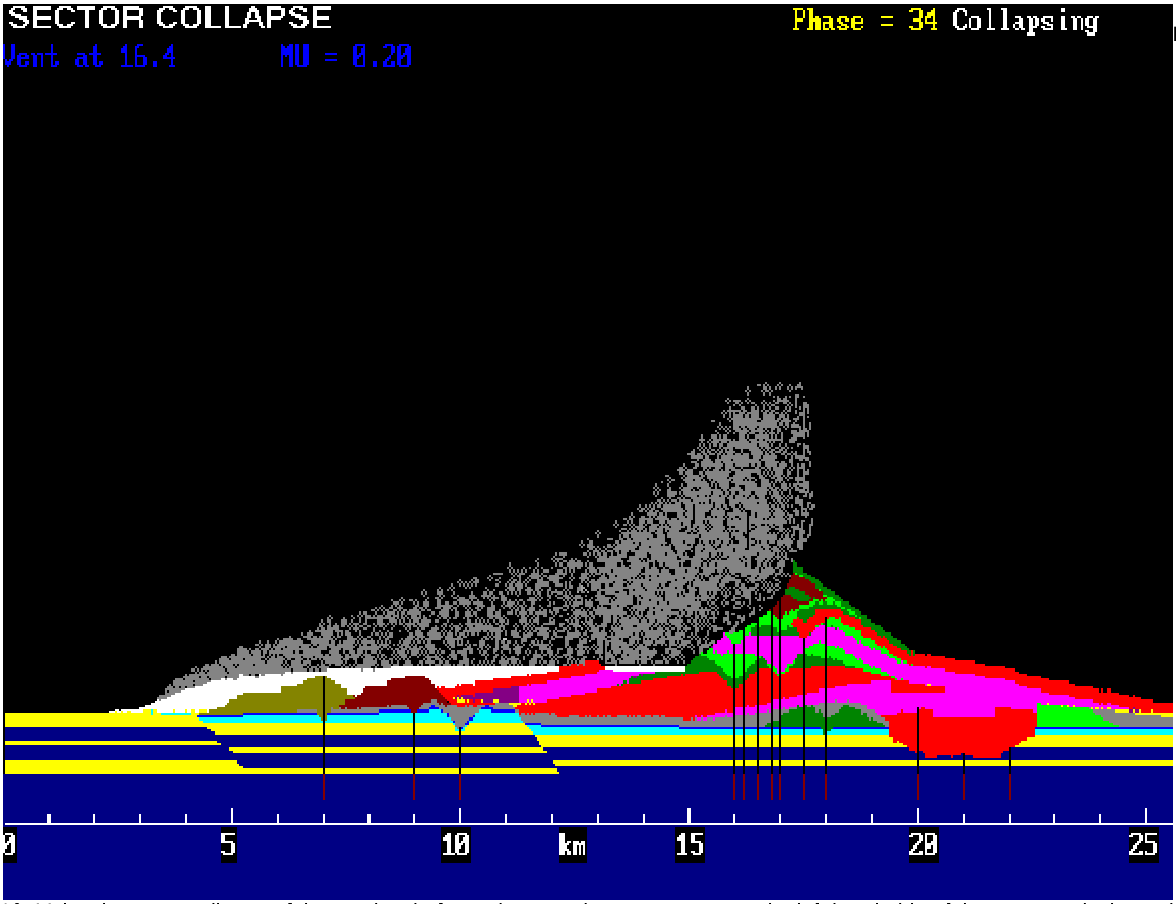


Fig. 10. Volcanic sector collapse of the previously formed composite cone truncates the left-hand side of the cone producing a debris avalanche (white) that covers downslope topograph.

DISCUSSION

ERUPT is a versatile program for the personal computer that allows the visualization of several common volcanic eruptive processes. The program provides a level of detail sufficient for researchers in volcanology but simple enough for casual users to appreciate. To be able to realistically portray volcanic processes on the personal computer screen, several limitations or simplifications were utilized in the algorithms. For example, the spatial and temporal scales are approximate for the sake of ease in visualization. Also, the numerical representation of volcano physics has been greatly simplified such that simulations may be considered only semiquantitative.

One advantage of the program is the ease by which a user can interact to modify or test various sequences of events. This process can lead to a better understanding the physical processes involved and can help to make accurate reconstructions of complex volcanic structures.

An important use of the program is as a teaching aid. Because of its simplicity it can be operated at nearly all grade levels from elementary school through graduate school. At the most sophisticated levels the program can help researchers to reconstruct the most complex volcanic structures and to understand the evolution of a single volcano or a volcanic field.

ERUPT can also be used in simulation of volcanic hazards. By accurately reconstructing the form and stratigraphy of a potentially dangerous volcano, the user can animate future eruptive activity, which is useful for illustrating hazards to non-technical audiences. This feature is very important in areas where the menace of volcanism is poorly known.

ACKNOWLEDGMENTS

This work done under the auspices of the U. S. Department of Energy with support by Los Alamos National Laboratory's Laboratory Directed Research and Development funds.

Software distribution of **ERUPT** is planned to be handled by **RockWare** Scientific Software, who now distribute a shareware version. Please send requests to:

RockWare, Inc.

2221 East St.

Golden, CO 80401 USA

(303) 278-3534

or use your web browser to download ERUPT at www.rockware.com

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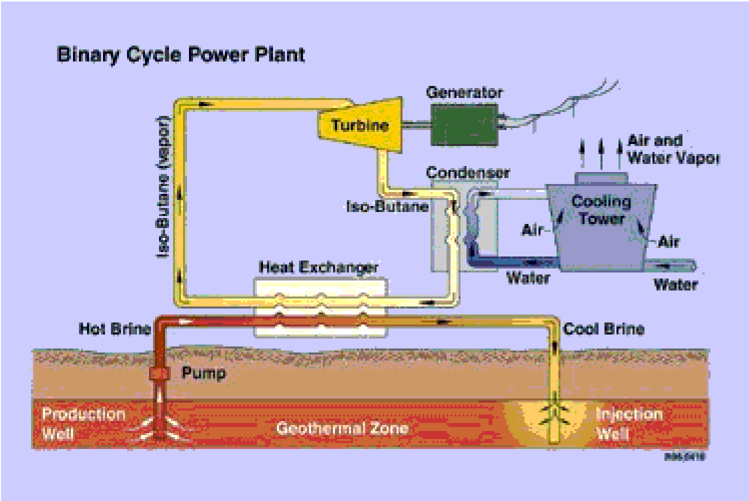
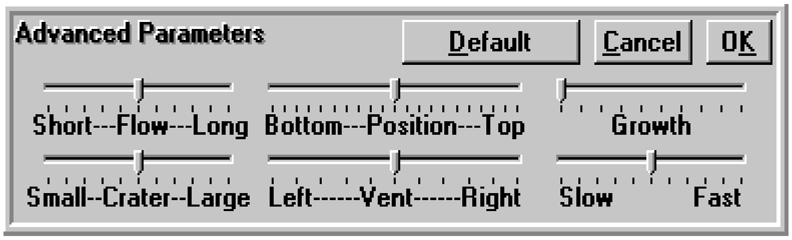
Geothermal Energy

Energy from the earth in the form of heat, geothermal energy most commonly is converted to electricity. Geothermal energy is generally extracted from the earth as steam and hot water. These materials reside below the surface of the earth in porous and fractured rocks call geothermal reservoirs. The hottest geothermal reservoirs are found in volcanic areas such as the Pacific ring of fire. Besides mineral resources, volcanoes are and economical resource for geothermal energy.



Advanced Parameters

New for ERUPT 3.0 are advanced parameters, accessible by pushing the "Advanced" button in the eruption parameter panel, that can be adjusted by slider bars. Depending on the eruption type selected user, some advanced parameters may be disabled (gray) or enabled (black). The Cancel button causes the program to ignore any changes made, the OK button applies these changes, and the Default button returns slider values to their initial programmed values.



Flow: If you have chosen Hawaiian or Peléean Dome eruption parameters, then the advanced parameters allow you do change the average length of lava flows.

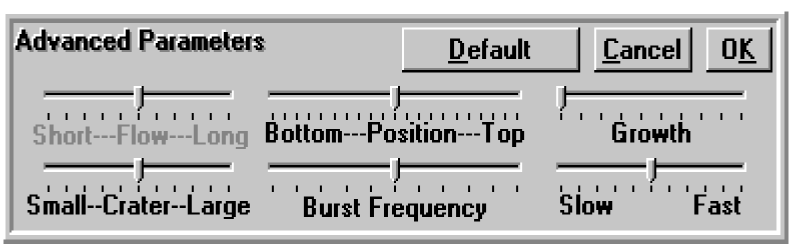
Crater: If you have chosen Strombolian, Plinian, or Pyroclastic Flow/Surge parameters, a scroll bar allows you to change the crater size dependence upon eruption strength or Heim-Coefficient.

Position: When maps are enabled via the options menu, the advanced parameters allow the user to also select the relative 3D position of the vent with a scroll bar. In this fashion the user can explicitly designate the 3D location for vents toward the top or bottom of the map. If these advanced parameters are not set for each new eruption cycle, then default, quasi-random vent locations and default lava flow lengths and crater sizes are used. This position can be easily set also using the Erupt 3D Vent Position window.

Vent: For caldera eruptions, the vent may be positioned nearer the left or right side of the caldera in order to simulate ring-fracture eruptions.

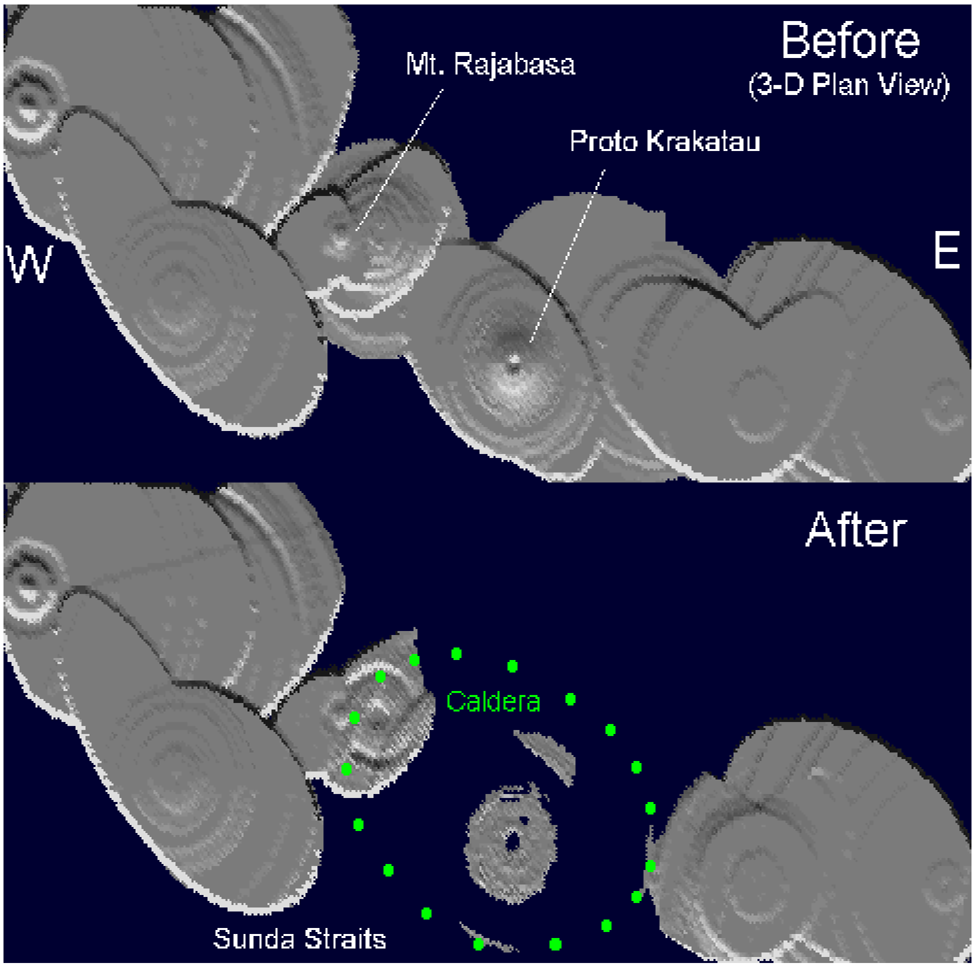
Slow/Fast: This adjustment controls the simulation speed in conjunction with the speed option chosen by the options menu. This adjustment is also displayed in the options panel in the Scale, Gravity, Speed tab. One may adjust it for better simulation speeds, which depend upon the users computer capabilities. This parameter will automatically be saved and used each time Erupt is started.

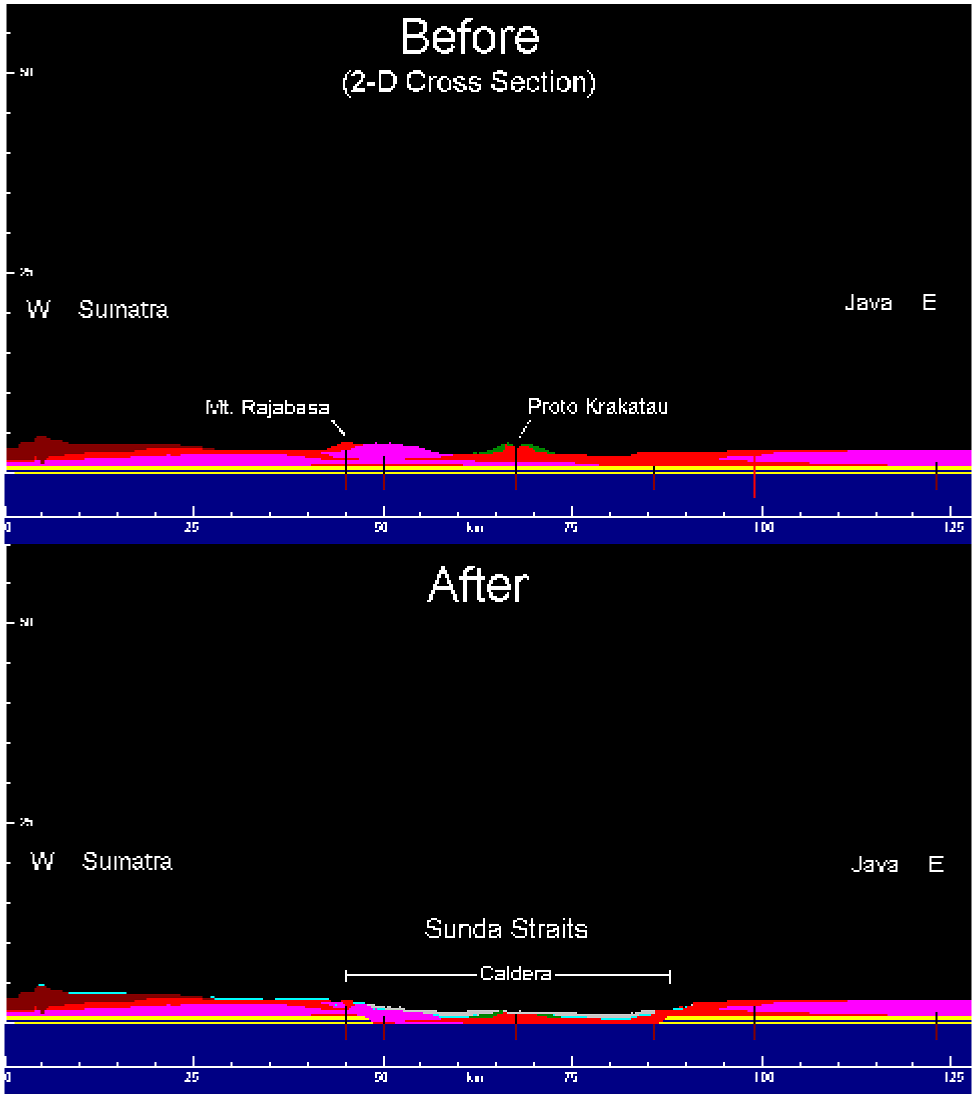
Burst Frequency: For Fumarolic/Phreatic eruptions, this slider determines the average frequency of Phreatic blasts during these eruptions. The frequency increase as the slider is moved to the right.



Example Use of Advanced Capabilities of Erupt

An example of an advanced use of Erupt is shown below by before and after cross-sections and topographic plots. By utilizing mapping capabilities and 3-D vent positioning as series of volcanic vents produce a simulated view of the meeting of Java (E) and Sumatra (W) at the predecessor of Krakatau volcano shown as *Proto Krakatau*. A historian David Keys hypothesizes that huge caldera-collapse eruptions at Proto Krakatau occurred around 535 AD and resulted in the separation of Sumatra from Java, producing the Sunda Straits.




Before
(2-D Cross Section)
W Sumatra
Java E
Mt. Rajabasa
Proto Krakatau
0
25
50
km
75
100
125
After
W Sumatra
Java E
Sunda Straits
Caldera
0
25
50
km
75
100
125

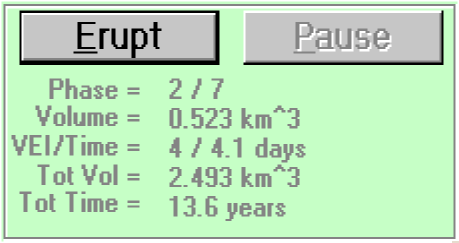
Erupt 3D

Erupt uses a sophisticated method to calculate three-dimensional displays of a volcano/volcanic field. Rather than consuming immense computational time in calculating precise data for each point in a map area, Erupt employs an approximation algorithm that predicts three-dimensional distribution of each eruption so that the user can then view plan (map) and topographic renderings of their simulations. In addition the 3D capabilities have been extended with the addition of the Erupt3D Viewer, which allows the user to explore the graphical detail by navigating through the 3D world calculated by Erupt3

Erupt 3D capabilities are an option that can be selected from the options menu by checking "Enable Maps". If the option "Enable Map 3D Position" is also chosen, then the user may select the vertical position of each vent via the Advanced Parameters menu or Erupt 3D Vent Position window, otherwise vents are position along a line through the center of the map.

The 3D feature of Erupt allows saving DEM (digital elevation model) files as well as the capability of opening them as well.

VEI (Volcanic Explosivity Index)



For Help on the Erupt Button press 

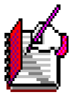
For Help on the Pause/Stop Button press 

How do volcanologists measure how big an eruption is? The "bigness" of a volcanic eruption can depend upon many features, but the following eruption magnitude scale - called the **Volcanic Explosivity Index or VEI** - is primarily dependent upon the volume of an eruption. Every year about 60 volcanoes erupt, but most of the activity is pretty weak. According to this scale, really huge eruptions don't happen very often, fortunately!

VEI	Description	Plume Height	Volume	Classification	How often	Example
0	non-explosive	<100 m	1000s m3	Hawaiian	daily	Kilauea
1	gentle	100-1000 m	10,000s m3	Haw/Strombolian	daily	Stromboli
2	explosive	1-5 km	1,000,000s m3	Strom/Vulcanian	weekly	Galeras, 1992
3	severe	3-15 km	10,000,000s m3	Vulcanian	yearly	Ruiz, 1985
4	cataclysmic	10-25 km	100,000,000s m3	Vulc/Plinian	10's of years	Galunggung, 1982
5	paroxysmal	>25 km	1 km3	Plinian	100's of years	St. Helens, 1981
6	colossal	>25 km	10s km3	Plin/Ultra-Plinian	100's of years	Krakatau, 1883
7	super-colossal	>25 km	100s km3	Ultra-Plinian	1000's of years	Tambora, 1815
8	mega-colossal	>25 km	1,000s km3	Ultra-Plinian	10,000's of years	Yellowstone, 2 Ma

Recording

The Erupt recorder adds an important capability to eruption simulations, the ability to recreate a given eruption sequence. By enabling the recorder function, the program records all the variables assigned and calculated during a simulation, such as the maturation of a composite cone through stages of lava flow, Strombolian eruptions, changing vent position, etc. Once the simulation is complete, the record is saved as a record file. This file can be opened in the future to playback the simulation, or it can be edited both from within Erupt and by using the program EruptEdit.



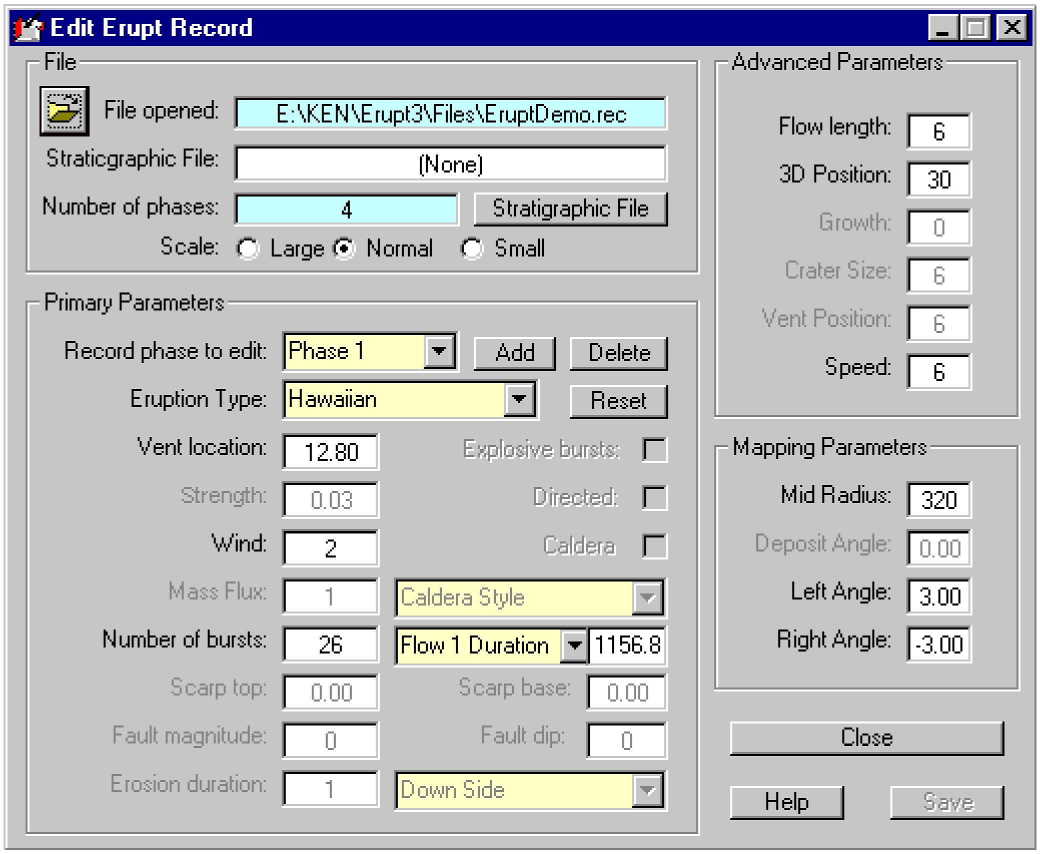
Record Editing

Once a record file has been opened or created, it can be edited by using the menu item 'Edit Record'. Alternatively, running EruptEdit by itself, a file can be opened or created. The edit window displays the contents of the opened record, showing the stratigraphic file (if any) upon which the recorded eruption cycles are deposited, and all the eruption parameters (including primary, advanced, and mapping parameters) for each recorded phase.

While the advanced parameters reflect settings recorded from the advanced parameter panel in Erupt, the mapping parameters are not available to the user while running Erupt; they are calculated by the program to get the average radius (mid radius) of erupted units, the deposit angle or skewness of pyroclastic deposits, and the left and right angles (skewnesses) of lava flows.

A given phase can be edited by selecting it and then changing its parameters. Phases may also be added and deleted. If a phase is added, you must then choose an eruption type to proceed. If you wish to return to the original record, press the reset button at any time.

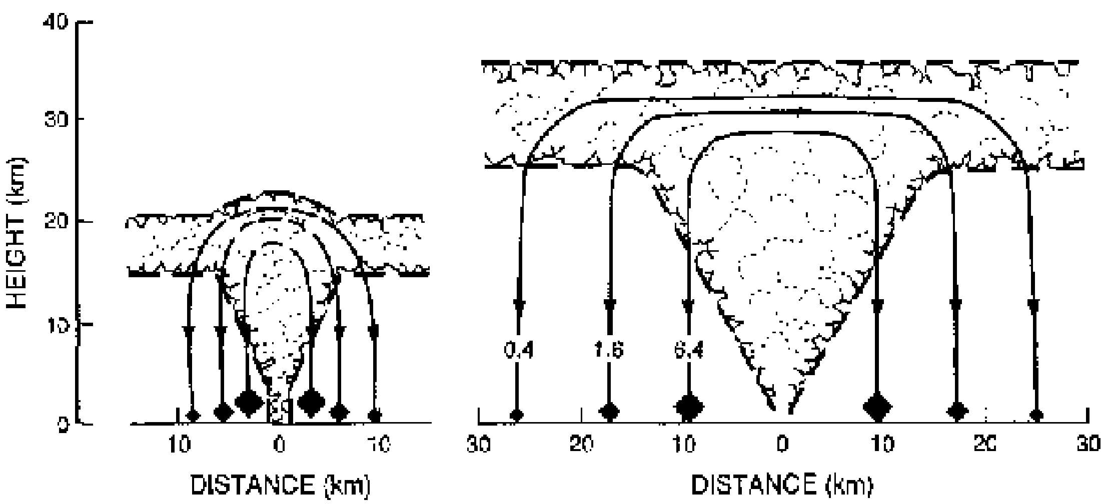
Once you have completed editing, choosing the 'Cancel' button ignores any changes, but choosing the 'OK' button applies the changes to the current Erupt session with the option of saving the file to disk.


Edit Erupt Record
File
File opened:
E:\KEN\Erupt3\Files\EruptDemo.rec
Straticgraphic File:
(None)
Number of phases:
4
Stratigraphic File
Scale:
Large
Normal
Small
Primary Parameters
Record phase to edit:
Phase 1
Add
Delete
Eruption Type:
Hawaiian
Reset
Vent location:
12.80
Explosive bursts:
Strength:
0.03
Directed:
Wind:
2
Caldera
Mass Flux:
1
Caldera Style
Number of bursts:
26
Flow 1 Duration
1156.8
Scarp top:
0.00
Scarp base:
0.00
Fault magnitude:
0
Fault dip:
0
Erosion duration:
1
Down Side
Advanced Parameters
Flow length:
6
3D Position:
30
Growth:
0
Crater Size:
6
Vent Position:
6
Speed:
6
Mapping Parameters
Mid Radius:
320
Deposit Angle:
0.00
Left Angle:
3.00
Right Angle:
-3.00
Close
Help
Save

Plinian Tephra (Pumice and Ash)

Plinian eruption thrust columns of steam, ash, and pumice high into the atmospere. These eruption columns often spread out in an anvil-shaped or umbrella-like cloud that drifts with the wind. While pumice and larger tephra fall near the volcano, finer-grained tephra (mostly ash) drifts considerable distance before falling back to the ground. This tephra blankets the ground for many kilometers around the volcano and forms what volcanologists call a fallout deposit (tephra fall, pumice fall, ash fall).

Plinian fallout is simulated by ERUPT based on models developed by volcanologists for predicting the distance from a volcano pumice and ash will be deposited. These models relate the range of fallout to the height of the eruption column, a function of the mass eruption rate. The higher the column the further pumice and ash will drift before it falls to the ground. In the diagram below, the trajectories of pumice fragments of several different sizes (cm) are portrayed with larger pieces falling closer to the volcano.



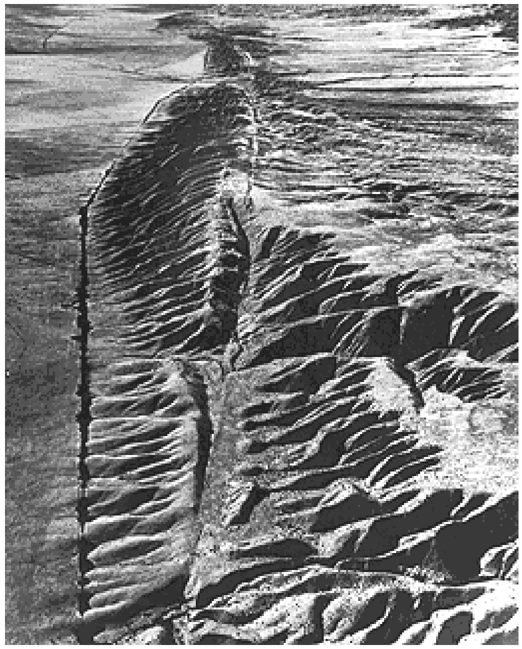
Pyroclastic Flow/Surge:

Pyroclastic flows (also known as Nuées Ardentes or glowing clouds) and surges are laterally moving clouds of pumice, ash, and gas moving at hurricane speeds downslope from the vent. These eruptions build up **Erosion/Sediments:**

Erosion events cause a smoothing of the topographic profile by a mathematical algorithm designed to simulate natural erosion. While higher topographic points are truncated, lower areas are filled with sediments derived from the erosion event.ash and pumice deposits (often bedded) during explosive eruptions, often the most hazardous type of volcanic activity. They are typically associated with Vulcanian, Surtseyan, Peléean, and Plinian eruptions.

Fault

A linear or curvi-linear break in the earth's crust along which displacement of rocks has occurred. Erupt simulates normal faults, which produce vertical displacement and generally dip (slope) in the direction of the downthrown side. Curvi-linear normal faults also mark the margins of calderas. Other kinds of faults include thrust (reverse) and strike-slip faults (shown below).



The San Andreas fault in California.

New for ERUPT 3.0

ERUPT 3.0 contains a number of improvements and additional capabilities over previous versions that have been distributed as shareware.

Among these new improvements and capabilities are the display of detailed stratigraphy, geological maps, and topographic views, which are accessible through the view menu. Status Bars keep the user informed of current ERUPT settings and context-sensitive help (when the cursor displays a question mark just click on the item for instant help). A ToolBar has been added and can be displayed (via the options menu, now available also as an option tab panel) to facilitate menu selections.

These additional features make ERUPT 3.0 even more flexible:

Fumarolic/Phreatic eruption parameters Passive steam and tephra emission with optional explosive bursts.

3D Development of map and 3D topographic views of erupted stratigraphy.

Digital Elevation Models (DEM) Capability to export and import DEM files.

Recording Create record files that capture every aspect of an eruptive simulation and play them back at a future time.

Scale Changeable horizontal/vertical scales for simulating small to large volcanoes and volcanic fields.

ToolBar Convenient execution of menu selections.

Advanced Parameters Designed to give more control over eruption characteristics.

Erupt WWW An internet page devoted to Erupt3 and its users..

Graphics capture Easily make copies of Erupt3 graphics for simple pasting into other graphics-capable programs

Erupt update utility Keeps your version up-to-date as periodic improvements evolve and are posted.

Encyclopedic help Useful for classroom application and for educational purposes.

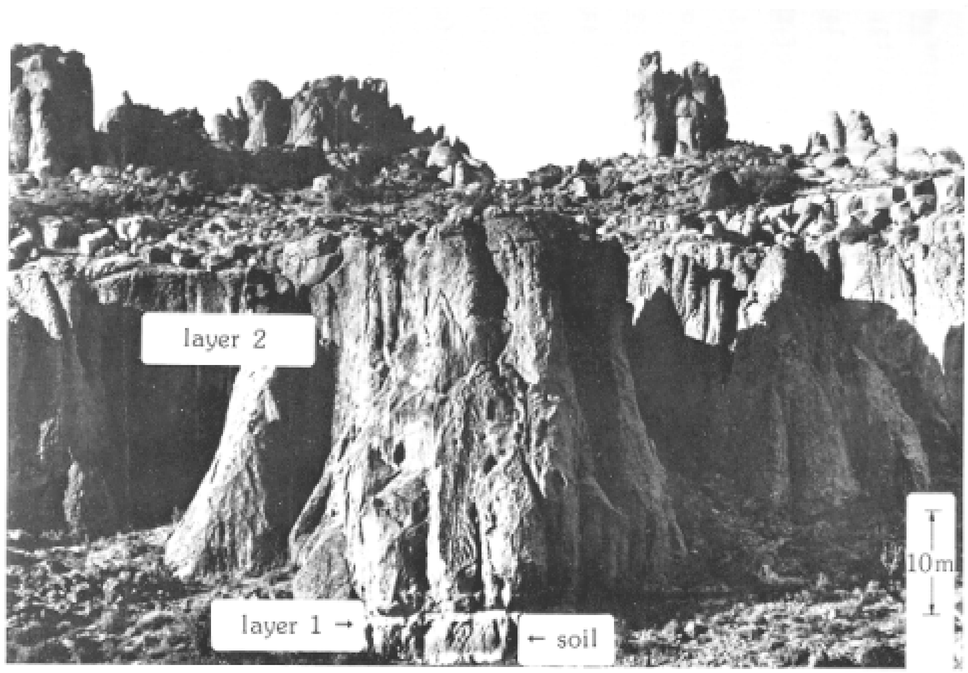
Stratigraphy:

Stratigraphy is the sequence of ash/lava layers emplaced by eruptions at various positions around a volcano. Study of stratigraphy reveals the eruptive history of a volcano and is a primary method used by volcanologists. ERUPT graphically shows stratigraphy by using different colors to represent different eruption types. A close-up view of the stratigraphy can be displayed by choosing "View Stratigraphy" .

Pyroclastic Flow and Surge Deposits

Contrasted to those deposits from Plinian eruption that form by fallout of pumice and ash from the atmosphere, Vulcanian/Surtseyan eruptions typically form pyroclastic flow and surge deposits are emplaced by currents of pumice and ash that move downslope from the volcano, often at hurricane velocities. Whereas surge deposits generally show centimeter to decimeter thick bedding, pyroclastic flow deposits may be massive an tens to hundreds of meters thick. Where this pumice and ash consolidates it is call tuff.

Bedded pumice and ash in a pyroclastic surge deposit.



Peach Springs Tuff in western Arizona consists of pyroclastic flow deposits welded into hard rock (ignimbrite) by the high temperature of the pumice and ash when it was emplaced. Layer 1 deposits are pumice fall and pyroclastic surge deposits, and layer 2 represents the body of the flow.

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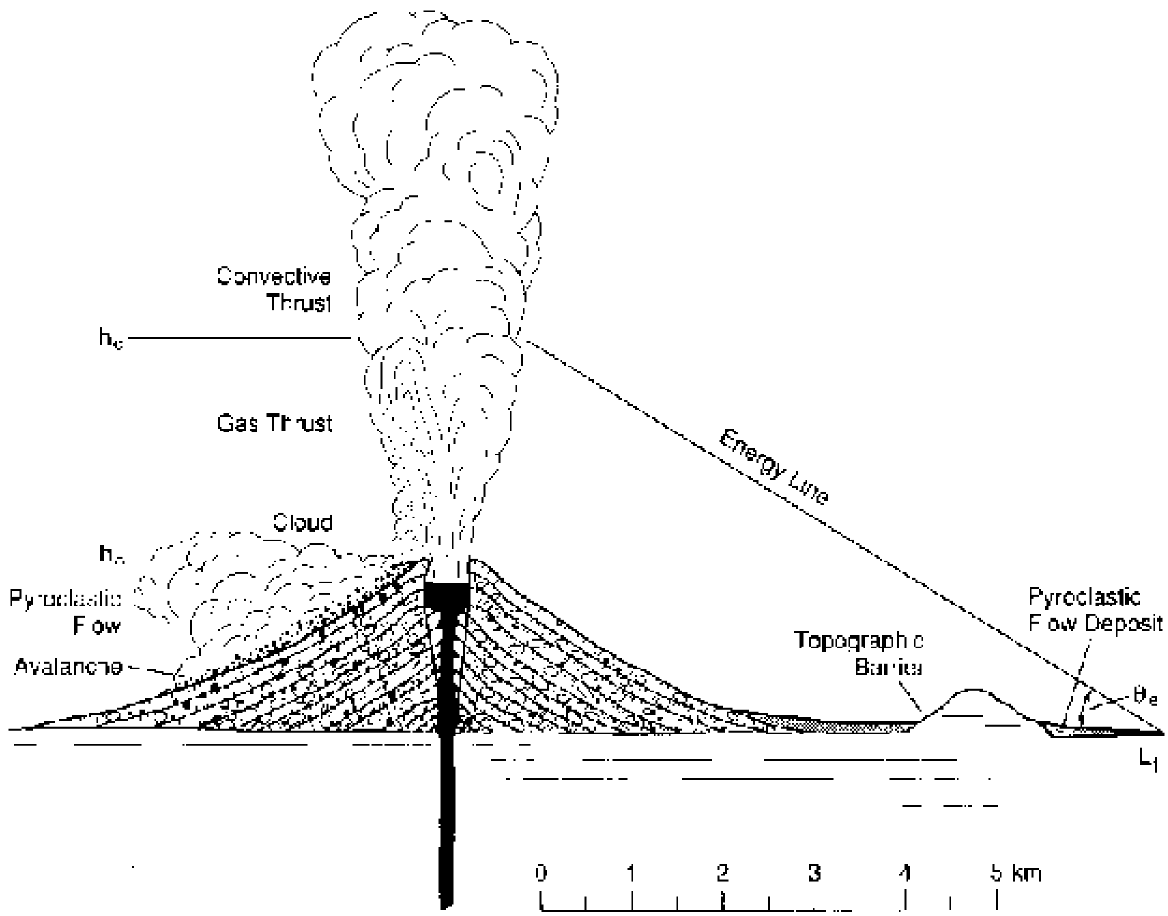
Pyroclastic flow erupted from Mount St. Helens.

Pyroclastic flows and surges can move a great distance from the vent, and they display considerable mobility in flowing over and around obstacles. Essentially they are gravity-driven currents, denser than air. The distance to which they move is basically related to initial speed or potential energy. As they move away from the vent, their potential energy is converted to kinetic energy, and the rate of conversion is dictated by their *energy line*, a graphical portrayal of how their energy decays as they flow away from the vent and overcome frictional forces. The top of the energy line is conveniently portrayed as the height within the eruptive column from which pyroclastic flows and surges begin to collapse back to the ground (known as the top of the *gas thrust* region of the column). The tangent of the energy line slope is known as the *Heim* coefficient. Weaker eruptions tend to have higher coefficients and thus have steeper energy lines that meet the ground nearer the vent. Where the energy line intersects the ground is where the pyroclastic flow or surge will come to a rest. If a flow or surge encounters a barrier like a small hill, it will be able to surmount it if its top is below the energy line. If not the flow stops or must move around the side of the hill where the energy line is above the hill's slopes.

ERUPT simulates pyroclastic flows and surges in Vulcanian/Surtseyan eruptions by solving the energy line problem for whatever topography exists around the volcano. Stronger eruptions require a lower Heim coefficient, but lower coefficients are coupled to a higher gas thrust region.


Convective
Thrust
h_c
Gas Thrust
Energy Line
Cloud
h_a
Pyroclastic
Flow
Avalanche
Topographic
Barrier
Pyroclastic
Flow Deposit
θ_e
L_f
0
1
2
3
4
5 km

Debris Avalanche

Eruptive collapse of a volcanic edifice leads to a downslope avalanche of broken lava and ash, generally called a debris avalanche. If the collapse destroys only a portion of the edifice, it is called a sector collapse. The avalanche deposit forms an apron of broken rock and ash that extends downslope and outward from the volcano.

Mount St Helens 1980 debris avalanche.

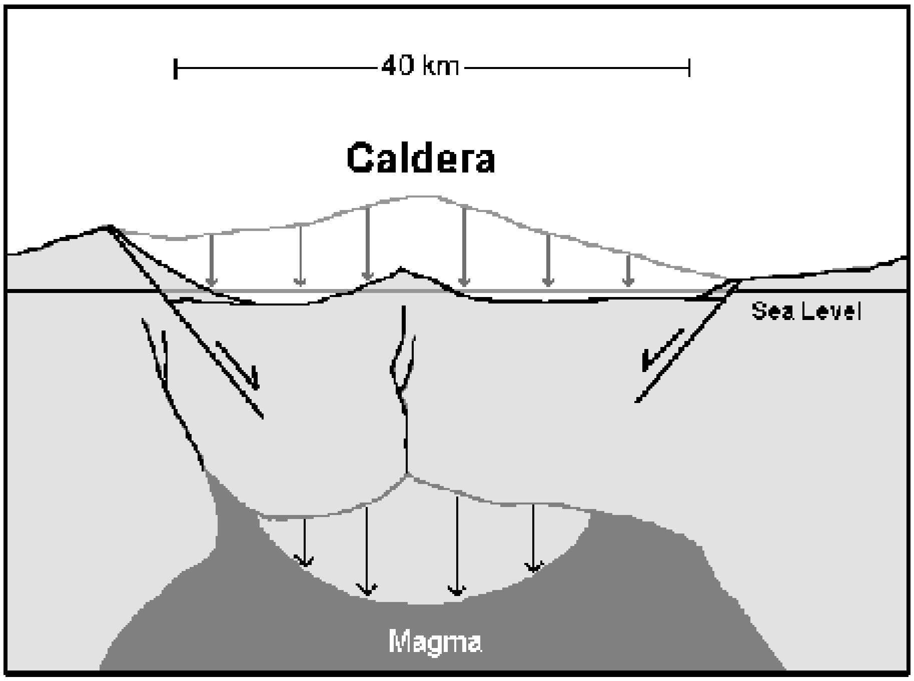
Basaltic (Mafic) Lava:

This lava is a dark grey or black colored lava (simulated by the Hawaiian parameter) of relatively low viscosity (high fluidity). It is typical of eruptions in Hawaii. It forms relatively thin lava flows that built up to form a shield volcano.

A basaltic lava flow on Hawaii

Calderas and Maar craters

Calderas are large, often many kilometers in diameter, craters that form by collapse of a volcano down into the portion of a magma chamber that has been emptied during large Plinian and Vulcanian eruptions. Calderas may subsequently be filled by sediments, lakes, and new volcanic vents, such as domes and lava flow, a situation called resurgence. Two styles of calderas can be simulated by ERUPT. The Mazama type, shown below, form by collapse of a volcanic edifice, such as a composite cone and may reach several or more kilometers in diameter. The Valles type are generally much larger, reaching several tens of kilometers in diameter, and they may encompass a number of volcanic vents, thus having a lower topographic profile than the Mazama type.



Schematic cross-section of a collapse caldera (Valles Type).

Crater Lake caldera (Mazama Type), Oregon, after a snow fall.

Maar craters also form by collapse due to excavation of rocks below the vent during Surtseyan eruption and in response to diatreme eruption. Steep walled craters that extend below the general level of the surrounding topography are termed maar craters. Tuff rings are deposits of fallout and pyroclastic surge/flow deposits that build a gently sloping apron of ash that extends away from the crater. Tuff cones are steep sided cones of ash surrounding a maar crater.

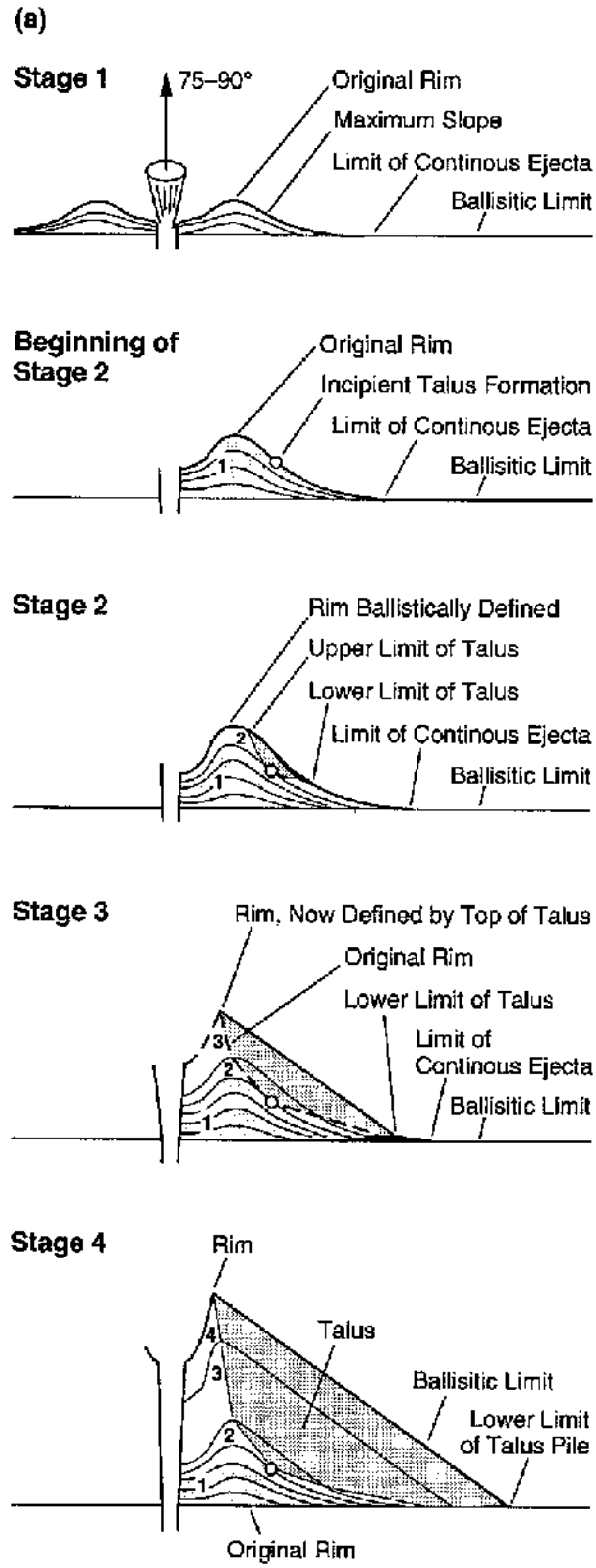
Crater Elegante maar in Sonora, Mexico is ~ 1.6 km in diameter.

Scoria (Cinder)

Centimeter to decimeter-sized fragments of vesicular basalt or andesite generally produced by Strombolian eruption. This material blankets the landscape around a vent in many places building a scoria (cinder) cone.

Merriam Crater scoria cone in northern Arizona.

The diagram below illustrates how a Strombolian eruption forms a scoria cone. The eruption produces a jet of red-hot scoria (cinders) that emerges from the vent as a spreading fountain. Each pyroclast (scoria piece) follows a ballistic (parabolic) path, arching up into the sky and falling back to earth. The distance from the vent at which scoria lands depends on the speed of ejection and the angle of ejection. Since their is a range of possible speeds and angles, the millions of scoria fragments ejected produces a deposit of scoria whose thickness is maximum at a distance from the vent dictated by the most probable ballistic range (Stage 1). As the scoria continue to pile up, the resulting deposit forms slopes which are unstable (greater than a typical angle of repose of about 25º), and they tend to slide down forming talus (Stage 2). With further growth, the slopes of the scoria cone become those resulting from the secondary talus (Stage 3). Because of the talus formation, a scoria cone can grow in diameter larger than the ballistic limit (Stage 4). All of these stages are simulated by ERUPT for Strombolian eruptions, that is a range of ballistic trajectories is computed and after each burst, the deposited fragments are subject to further downslope movement if they are on a slope greater than a typical angle of repose.


(a)
Stage 1
75–90°
Original Rim
Maximum Slope
Limit of Continous Ejecta
Ballisitic Limit
Beginning of Stage 2
Original Rim
Incipient Talus Formation
Limit of Continous Ejecta
Ballisitic Limit
Stage 2
Rim Ballistically Defined
Upper Limit of Talus
Lower Limit of Talus
Limit of Continous Ejecta
Ballisitic Limit
Stage 3
Rim, Now Defined by Top of Talus
Original Rim
Lower Limit of Talus
Limit of Continous Ejecta
Ballisitic Limit
Stage 4
Rim
Talus
Ballisitic Limit
Lower Limit of Talus Pile
Original Rim

Composite Cone

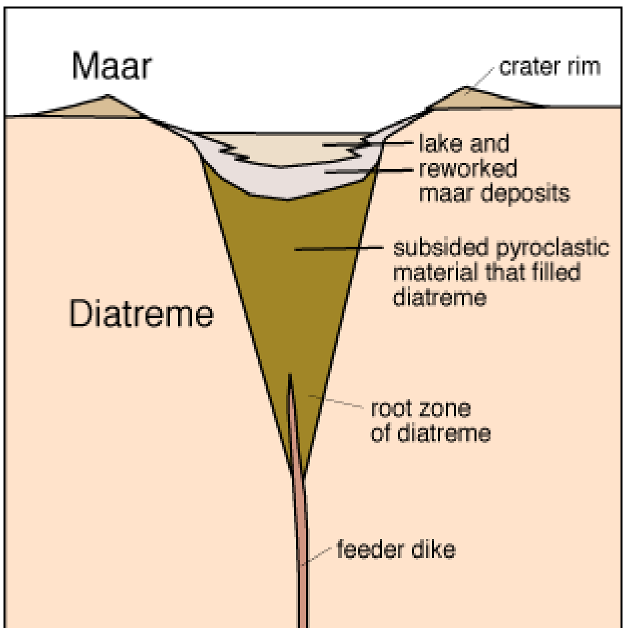
Also known as stratvolcanoes, these volcanoes tend to build high-standing conical shaped structures composed of both lava and tephra. Because they are not just explosive or effusive vents, but display a variety of eruptive activity and products, they are get the term composite.

Mt. Rainier in Washington is a glaciated composite cone, consisting of lava flows and domes, tephra layers, and debris flows.

Diatreme

A diatreme is a deep-rooted volcano, formed by rise of gas-rich magma from the mantle along a pipe-like or fissure conduit. The rise of this magma is thought to be violent, tearing the magma apart and carrying along abundant and often large pieces of country rock as it bores its way to the surface. Surface eruptions can be Vulcanian/Surtseyan or Strombolian, and generally produce a maar crater. Where diatreme craters are identified, it is generally because of the unusual composition of their mafic/ultramafic products, which include fragments of the earth's lower crust and upper mantle known as nodules. In many places around the world, including Kimberly, South Africa, diatreme products include diamonds (hence the name kimberlite), but more common are abundant olivine, pyroxene, and garnet-bearing nodules. Most known diatremes are quite old and have been eroded down to expose only their root conduit, which can be of harder rock than surrounding materials and left exposed as a spire-like monument.

Erupt simulates diatreme emplacement for low power Strombolian and Vulcanian/Surtseyan eruptions, by showing the gradual rise of mafic magma (purple) by brecciation and fracturing of overlying strata. Once the diatreme breaks the surface, Erupt starts simulation of the associated eruptive type, which creates a scoria cone or maar crater above the diatreme. To simulate a diatreme, a sufficient thickness of stratigraphic layers needs to have been created. One way to do this is to open the default stratigraphic file "Erupt3.str" and then change to a smaller scale, if possible. In this way the user can better see the detail of diatreme eruption.



Model of a maar-diatreme volcano. Simplified from Lorenz (1986).

Church Rock diatreme in Arizona.

Coliseum diatreme in Arizona, showing a surface manifestation as a maar crater.

Dome:

Silicic lava (simulated by the Peléean parameter) is viscous and forms relatively thick, stubby flows. Repeated and continued extrusion of silicic lava at a vent forms lava domes. These volcanoes generally have an average diameter of less than several km and can reach heights of a km or more. These are steep sided and very rough surfaced.

A rhyolite dome in the Mono Craters area of California.

Mount St. Helens lava dome.

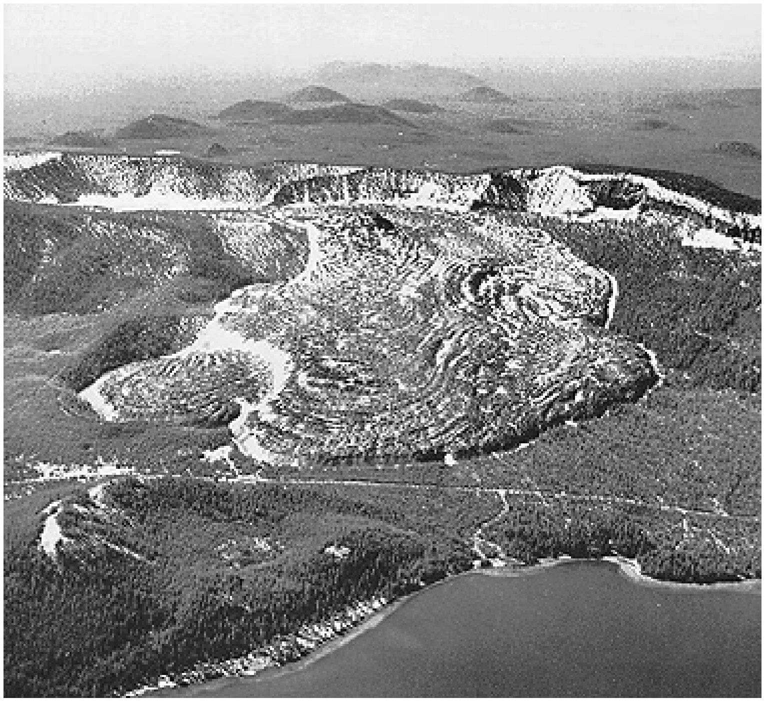
Shield Volcano

Hawaiian (basaltic lava) eruptions tend to build shield volcanoes that are broad mountains with low flank slopes. In profile these volcanoes look like an upturned shield. Many shield volcanoes have summit calderas. They consist of hundreds or thousands of individual lava flows that have emanated from the summit vent or from flank vents and fissures.

Mauna Loa shield volcano in Hawaii.

Silicic Lava:

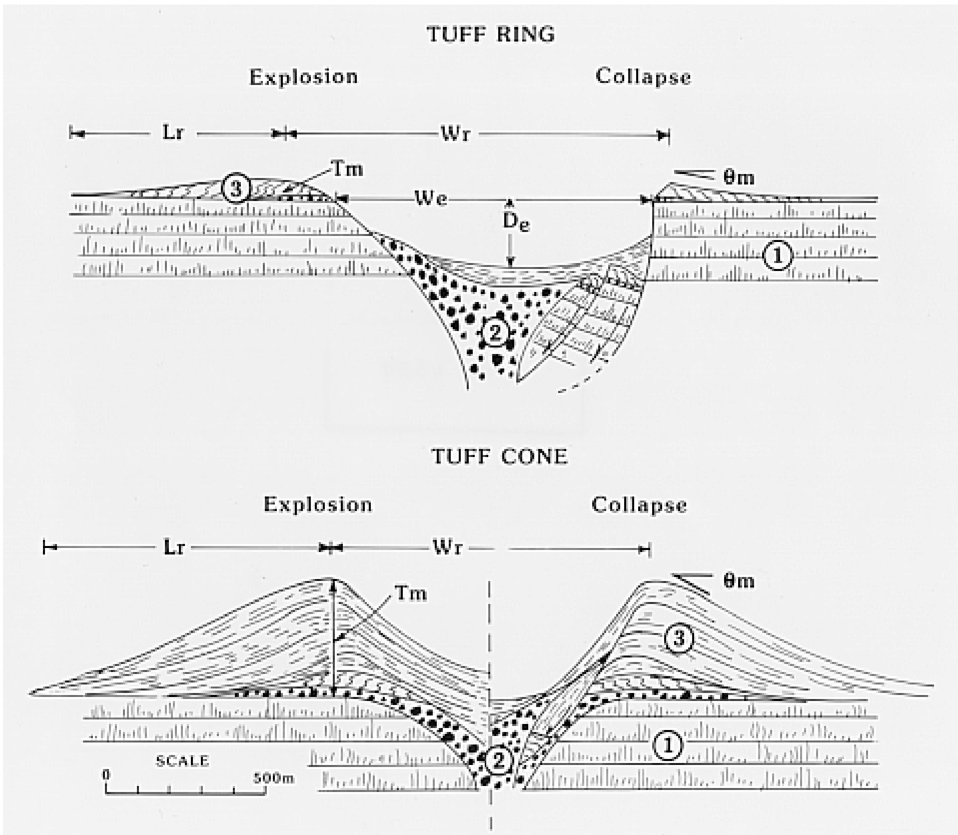
This lava (simulated by the Peléean parameter), termed rhyolite or dacite, is a medium grey to nearly white in color and can be black if it is obsidian or even a brown to reddish brown color. It is of high viscosity (low fluidity), such that it forms thick, steep-sided flow that build up to form a lava dome.



Big Obsidian flow at Newberry volcano, Oregon.

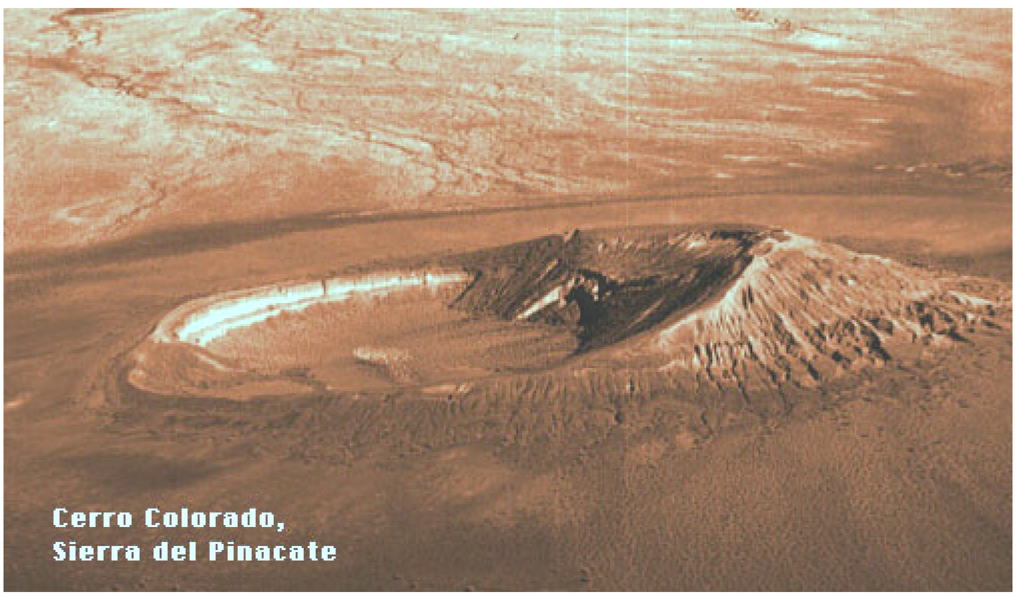
Tuff Cones and Rings

These volcanic vents generally consist of a relatively wide crater often deeper than the surrounding country side (maar crater). The craters are surrounded by an apron of ash, consolidated into tuff. Low profile vents are called tuff rings, where as taller structures are called tuff cones. Typically formed by Vulcanian/Surtseyan eruptions that involve steam explosions caused by vaporization of near surface water by magma, these vent forms are second only to cinder cones as the most common vent form on earth.



Schematic cross-sections of a tuff ring and a tuff cone. Rock 1 denotes country rock through which hydrovolcanic (Vulcanian/Surtseyan) eruptions penetrate. Rock 2 is a coarse vent-filling explosion breccia. Rock 3 is finely laminated pyroclastic surge deposits (tuff ring) or thickly bedded, massive tuff breccia (tuff cone). The slope angle denoted by the Greek letter theta is just a few degrees for tuff rings and up to 25 degrees in tuff cones.

Tuff ring, approximately 1.6 km in diameter, standing only ~25 m above the desert floor in Mexico.



Tuff cone standing ~100 m above the desert floor in Mexico.

Technical Support for Erupt

Before contacting support, first identify your computer and operating system. Some common problems are listed here.

Error message: Infrequently during a simulation of a given eruption type, an error message for that eruption type might be displayed, for which the user has only one option and that is to respond by clicking the "OK" button. While Erupt should continue to function properly, please contact the author (email preferred) and describe the conditions under which the error message appeared.

 **Keep you Erupt files up-to-date:** Be sure to check for new versions using the EruptUpdate program or by choosing 'Update' from the File menu. In some cases, new versions may fix a problem you are experiencing. In certain circumstances, Erupt Update mail fail to establish a good FTP connection. If the program does not automatically connect for you (as in the case of a dial-up connection) try making the connection before starting the program. The most recent update file can be downloaded from the Erupt-User page. Once downloaded, this program will automatically start Update in local mode and install newer file versions.

 **Notify me about your problems:** Use the EruptComments program (or open in from the Help menu) to send comments about the problem(s) you are experiencing to the Erupt FTP server (or by email to erupt@lanl.gov) with a description of your simulation. I will try to answer your questions to solve problems.

Trouble with Internet connection: While using the Erupt WWW viewer, Erupt Update, sending comments, or (re)sending your registration information, Erupt attempts to establish a connection with the internet via FTP or HTTP protocol. If a connection via LAN or Proxy is not detected, then Erupt will attempt to establish a connection to your Internet Service Provider (ISP) via a modem dial-up networking connection (DUN). DUN is a built-in capability of all Windows 32-bit operating systems, but before it can operate, it must be configured by the user with one or more telephone connections to a defined ISP. When a DUN connection is required by Erupt, a connection panel will be shown, allowing the user to choose which ISP should be dialed and whether to automatically dial. These settings are shared by other Windows programs, such as web browsers and mail applications.

Potential problems arise during FTP sessions in the registration and comments windows. These problems come from the communication errors between Erupt and the FTP server caused by slow connections, server availability, and size of files being transferred (especially important for Erupt Update). If you encounter continued problems, please send email erupt@lanl.gov. If problems occur trying to use Erupt Update to get a new version, then you can download the update file from the Erupt User page via the Erupt WWW browser or other browser, and then run it locally on your hard drive.

Sound option disabled: This situation means that your computer does not have a recognizable sound device and eruptions are silent. The sound option will be disabled and unchecked.

No sounds: If the sound option is enabled and checked and no sounds are heard during an eruption simulation, first check to see if your sound driver is properly installed, the "wave out" device is enabled, and the volume settings are correct in your Windows volume control applet (alternatively view the Erupt options panel to check/test the current volume setting). If these settings work, and sound normally functions correctly for your computer, then the sound files for Erupt may be missing. Check the "Sounds" subdirectory of the directory where you installed Erupt (e.g., C:\Program Files\Erupt 3.0\Sounds). The following files should exist.

Surge.wav
Collapse.wav
Dikecool.wav
Dikeint.wav
Dome.wav
Erode.wav
Fault.wav
Fumarole.wav
Lava.wav
Off.wav
Opening.wav
Stromb.wav
Closing.wav
Plinian.wav

If you have moved, edited, or substituted any of these files, sounds may not be heard. Be sure these file names exist.

Sound Loop: If sounds do not continue through entire eruption, then they are not "looping" correctly. This issue reflects a non-standard sound-card device driver on your system and there is no fix within Erupt for this condition.

Volume Control: If the volume control in the options panel produces no effects, then again, this issue reflects a non-standard sound-card device driver on your system and there is no fix within Erupt for this condition.

Stratigraphic display: If Erupt re-paints the stratigraphy in the Erupt window to all one color, or is all black after an eruption, choose "Refresh" from the View menu to redisplay the correct stratigraphic display.

Simulations speed: If simulations are too fast or too slow try adjusting the Slow/Fast advanced parameter to better suit your needs. This parameter will be saved for future Erupt sessions. Alternatively, try recalibrating the simulation speed via the speed option in the options menu.

If your simulation speed seems to running more slowly than usual, then first check that the View menu item "Capture" is not checked, then if that does not seem to help, close other programs that are running in the background.

DEM files: DEM files saved by other programs have their own specific file format. They contain header information (not used by Erupt) and may store data in vector or raster format. Opening such files has not been extensively tested in Erupt, and the user may have to resort to some clever editing to make Erupt recognize these files. Users who wish to explore this problem should contact the author (on the Erupt WWW page) and email him a copy of the file if it is not too large.

ERUPT Support

Erupt support is facilitated by registering your software with the author. Registration will put you on a mailing list for notification of updates; it will also facilitate getting help from the author either by email (erupt@lanl.gov), which is preferred, or by telephone (505-667-9202).

Some technical support is offered through this help file. If you are having problems with Erupt, please see the technical support section before contacting erupt@lanl.gov

Documentation of ERUPT is contained in the Los Alamos National Laboratory report LA-UR-91-3205, which may be obtained from the Geology/Geochemistry Group, EES-1, MS D462, Los Alamos National Laboratory, Los Alamos, NM 87545, USA or online at http://www-geo.lanl.gov/Wohletz/Erupt-Doc.htm. Registration of this version of ERUPT is optional.

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